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Investigation of the Environmental Pollution and Damage by Urban Traffic Noise and Exhaust Gases

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INVESTIGATION OF THE ENVIRONMENTAL POLLUTION AND DAMAGE BY URBAN TRAFFIC - NOISE AND EXHAUST GASES

(Untersuchung der Umweltbelaestigung und Umweltschaedigung durch den Strassenverkehr in Stadtgebieten - Laerm und Abgase -)

Part I. 1.2 Cost Estimate of Modifications on Vehicles to Reduce Noise Emission

(Teilstudie I. 1.2 Untersuchung der Kosten fuer Veraenderungen am Fahrzeug zur Verringerung der Laermemission)

by

Obering. Guenther Frietzsche, Director
Heinrich Gillet KG
Entwicklungsabteilung.

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Introductory Remarks

The European Economic Community "Office of Traffic" in Brussels commissioned the Department of Traffic of the Federal Republic, Ref. A 13/ A 14 in Bonn and the VDI in Duesseldorf to carry out an investigation "Survey of the Environmental Pollution and the Environmental Damage Due to Street Traffic in Urban Areas (Noise and Exhausts)".

The partial study I.I.2 "Cost Estimate for Modifications on Vehicles to Reduce Noise Emission" was awarded to Heinrich Gillet KG, Edenkoben, and was carried out under the supervision of Chief Engineer Guenther Frietzsche in 1971. The measurements were done by the Department for Research and Development of Heinrich Gillet KG on their own measuring tracks or on the testing tracks of participating car manufacturers. All evaluations were made by the same team.

The excellent cooperation of all coworkers, participating manufacturers and associations is gratefully acknowledged.

The results were discussed with the participating investigators and the VDI and adapted to the requirements of further evaluations.

This publication represents the detailed version.

In addition a short version was published limited to a summary of results and conclusions.

( ) Numbers in parentheses refer to the literature.

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Purpose of the Investigation

Survey of the Environmental Pollution and the Environmental Damage

Due to Street Traffic in Urban Areas (Noise and Exhausts)

Partial Study I.1.2

Cost Estimate for Modifications on Vehicles to Reduce Noise Emission.

1. General

1.1 Legislation Concerning the State of Technology

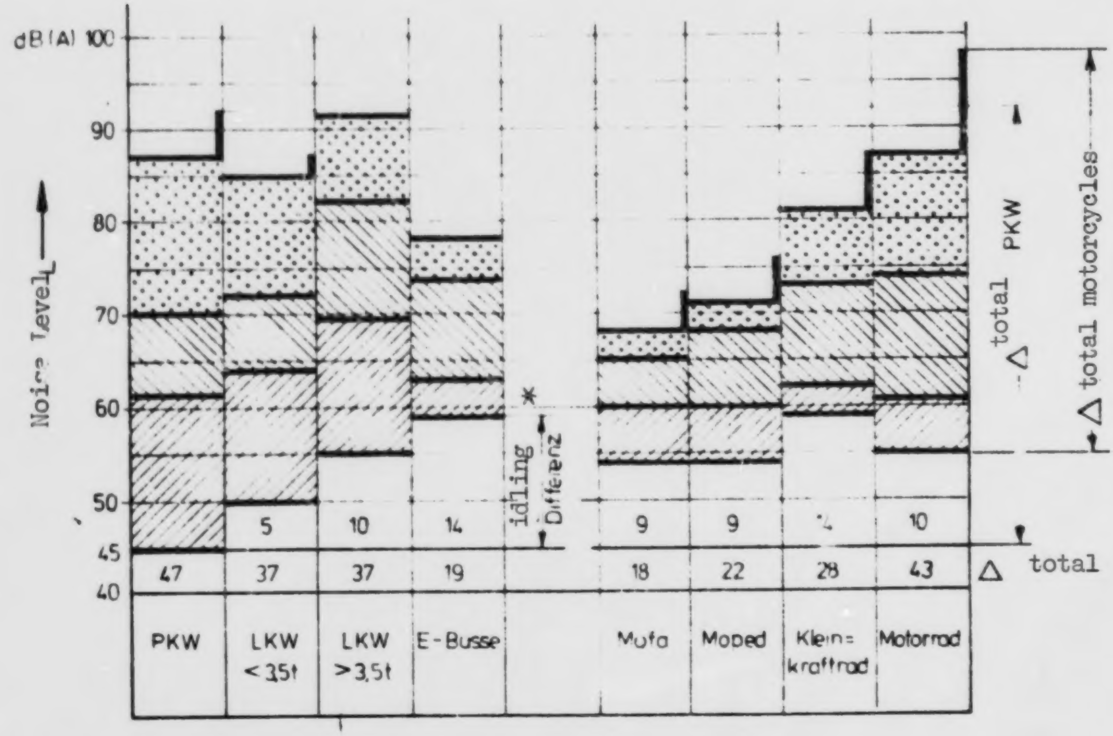
Many countries legislatively regulate the noise emission by motorized vehicles. The ISO-recommendation R 362 arose in cooperation with officials, experts of the car industry and international standardization. Legislation presently applicable in Germany is given in paragraph 49 StVZO (7). In it the tolerance values for type examinations are also given that can be continually reexamined.

Further ordinances to be mentioned are:

The EG-guide line of February 9. 1970 and regulation No. 9 that has already been adopted by various countries, but needs revision because of deviations in the tolerance values and operating conditions from the EG-guide line. Other national regulations, as for example in the USA, Great Britain, Sweden, Italy, have to be respected by the automobile industry when cars are to be exported into these countires.

Since noise levels of different types of vehicles vary greatly, which can amount to as much as 45 dB(A) between idling (depending on the idling level) and the maximal number of motor revolutions when accelerating (see fig. 1) maximal velocities and operating conditions that give maximal noise levels were made mandatory for the type examinations and limiting

Variation of the Noise Levels of Different Types of Vehicles in Urban Traffic in Various Operating Modes from a Distance of 7.5 m = △ Total



▨ Idling noise

▧ Constant speed at 30-50 km/h and deceleration

▒ Starts and Acceleration

| Peak Levels Due to Maneuvering

*. Idling difference gives the difference between lower idling noise level of agiven class of vehicles and the passenger cars.
△ total + idling difference + 45 dB(A) = peak level

values were stipulated for them.

These determine the state of technology. It approaches a similar level in different countries, yet it is by no means uniform within individual categories of vehicles at the present time.

1.2 Automobile Count, Distribution of Categories, Percentages of Registered Types of Vehicles.

Table 1 shows the existing number of vehicles as of 12/31/1969 and 7/1/1970. In table 2 existing passenger cars and station wagons are classified according to cubic capacity in the Federal Republic of Germany for the years 1968-1971.

In tables 3, 4 and 5 the percent distribution of light (under 3.5 t) and heavy (over 3.5 t) truck- and cycle production is given for the years 1969 and 1970. Percentages of 75% for trucks below 3.5 t and 60-98% for cycles show that the study is representative. The inspected types of trucks below 3.5 t represent 30-35 % of the annual production; a relatively high percentage for this group considering the great variety of types.

Table 6 gives the percentages of each passenger- and station wagon type according to classes of cubic capacity of the production for 1969 and 1970. In addition, the percentage of inspected types of vehicles in terms of the total number of existing vehicles according to the official statistics of the KBA as of July 1, 1970, is indicated. The figures prove that between 23 and 85% of all cars produced were covered in individual classes.

Since the overall number of vehicles comprises at least 10-15 years of production, the proportion of tested vehicles must necessarily be lower. Despite that fact, representative values for individual classes of vehicles

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Teilstudie I 1.2

Listing of Inventories of Motorized Vehicles in EWG-Countries and % Distribution

- Numbers are Taken from the Official Statistics of the KBA

— Inventories in 1000 —

Tabelle 1

Country	Date		Motorized Vehic Total	Passenger Cars	Trucks	Tractors	Cycles	
							Motorcycles	light motorcycles Moped + Mo's
Germany	1.7.70	Number	17 898	13 941	1 038	1 446	229	1 244
		% BRD	100,0	77,9	5,8	8,1	1,2	7,0
		% EWG	31,6	24,0	1,8	2,5	0.4	2.5
France	31.12.69	Number	19 279	11 670	1 810	49	-	5 750
		% Fr.	100,0	60,5	9,4	0,2	-	29,9
		% EWG	34,2	20,6	3,2	0,1	-	10,3
Italy	31.12.69	Number	14 136	9 328	1 187	596	1 285	2 040
		% Ital.	100,0	65,9	8,4	4,2	9,1	14,4
		% EWG	24,9	15,9	2,0	1,0	2,3	3.7
Netherlands	31.12.69	Number	2 537	2 225	301	11	-	-
		% NL.	100,0	87,7	11,9	0,4	-	-
		% EWG	4,5	3,9	0,6	0,0	-	-
Belgium	31.12.69	Number	2 612	1 896	290	-	46	380
		% Belg.	100,0	72,6	11,1	-	1,7	14,6
		% EWG	4,6	3,4	0,5	-	0,08	0,62
Luxemburg	1.1.70	Number	111	85	12	10	4	-
		% Lux.	100,0	76,6	10,8	9,0	3,6	-
		% EWG	0,2	0,17	0,02	0,01	0,0	-
Total	EWG	Number	56 573	38 845	4 638	2 112	1.564	9 414
		% EWG	100.0	68,57	8,12	3,61	2,78	16.92

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Automobile Count, Distribution into Categories, % of Registered

Types of Vehicles 1968 - 1971

Date : 1.7.   Numbers in [illegible]

Class	Cubic Capacity	Numbers %	1968	1969	1970	1971
1	0,00 bis 0,99 ltr.	Inventory	2005	1980	1959	1890
		%	17,2	15,7	14,0	12,5
2	1,00 bis 1,49 ltr.	Inventory	6260	6677	7275	7581
		%	53,6	53,0	52,2	50,2
3	1,50 bis 1,99 ltr.	Inventory	2076	2415	2923	3623
		%	17,8	19,2	21,0	24,0
4*	2,00 bis 2,99 ltr.	Inventory	499 (494)	597 (586)	747 (725)	883 (848)
		%	4,2	4,2	5,24	5,6
5	>3,00 ltr.	Inventory	(5)	(11)	(22)	(35)
		%		0,08	0,16	0,2
6		Inventory	843	916	1037	1138
		%	7,2	7,3	7,4	7,5
Total		Totals	11 683	12 585	13 941	15 115
		%	100,0	100,0	100,0	100,0

* Incl. Wankelmotors

(12) Numbers of class 5 included in class 4

(--) Numbers in class 4 indicating differences

List of Tested Busses and Trucks below 3.5 t Total Weight

Production Distribution for 1969 - 1970 from the VDA Statistics

No.	Key number	Production		
		Share 1969 %	Share 1970 %	
	Total	162 197	157 278	Because of the great variety of types of trucks an exact assignment of tested types to inventories of 7/1/1970 is not possible.
1	200	62,51	61,99	
2	201	1,03	0,64	
3	202	6,47	7,09	
4	203	2,64	3,69	
5	204	1,72	2,58	
Fraction of Tested Types of the Total Production of that Class		74,37	75,99	

Percent share in pieces = 120 626 (1969)
Percent share in pieces = 119 516 (1970)

Table 4

List of Tested Busses and Trucks above 3.5 t Total Weight

Classes and Production Distribution for 1969 - 1970 from the VDA Statistic

No.	Vehicle Key Number	Class (in Tons)	Production	
			Share 1969 %	Share 1970 %
	Quantity in pieces		110 [illegible]	130 [illegible]
1	310	4 - 6	7,77	7,53
2	313	4 - 6	2,[illegible]3	3,11
3	311	6 - 8	2,90	3,00
4	314	6 - 8	3,54	5,92
	-	8 - 10	-	-
	-	10 - 12	-	-
5	300	12 - 16	0,08	0,09
6	301	12 - 16	0,06	0,06
7	302	12 - 16	0,05	0,07
8	303	12 - 16	0,45	0,53
9	304	12 - 16	-	0,10
10	305	12 - 16	0,50	0,62
11	307	12 - 16	0,68	0,70
12	309	12 - 16	0,09	0,21
13	315	12 - 16	2,31	2,53
14	316	12 - 16	1,03	1,12
15	317	12 - 16	1,99	2,02
16	306	> 16	1,56	1,69
17	308	> 16	1,07	1,35
18	312	> 16	1,86	2,08
19	318	> 16	0,30	0,27
20	319	> 16	1,46	1,62
	Share of Tested Types in the Total Production of that Class		30,36	35,32

Because of the great variety of the types of trucks an exact assignment of the tested types to inventories of 7/1/1970 is not possible.

Percent share in pieces: 1969 = 33,512
1970 = 45,988

Table 5

List of Tested Cycles

Production Distribution for 1969 - 1970 from the VDA Statistic

No.	Type of Vehicle	Key Number	Production Share 1969 %	 Share 1970 %
	Mofa 25	Quantity in pieces	62 15[illegible]	71 698
1		400	48,[illegible]	58.5
2		401	5,[illegible]	19.[illegible]
3		402	26,[illegible]	23,[illegible]
Fraction of Tested Types in the Total Production of that Class			79,[illegible]	80,5
	[illegible]	Quantity in pieces	63 545	73 [illegible]30
4		500	22,[illegible]	23,0
5		501/502	[illegible]	28.0
6		503	38,[illegible]	37.0
Fraction of Tested Types in the Total Production of that Class			90,[illegible]	88.0
	Light Motorcycles	Quantity in pieces	4[illegible] [illegible]28	48 63[illegible]
7		600	[illegible]	22,[illegible]
8		601/602	[illegible]	[illegible]
9		603	[illegible]	3[illegible].
Fraction of Tested Types in the Total Production of that Class			[illegible]	97.0
	Motorcycles above 50 ccm	Quantity in pieces	1[illegible] 8[illegible]	2[illegible] 49[illegible]
10		[illegible]	15,[illegible]	[illegible]
11		7[illegible]1	-	3,
12		[illegible]02	[illegible]	9,
13		703	25,0	19,[illegible]
14		[illegible]4/705	5,0	28,
Share of Tested Types in the Total Production of that Class			59,[illegible]	[illegible]3,[illegible]

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Table 6
Sheet 1

List of Tested Passenger Cars and Stationwagons
Distribution of Production for 1969 - 1970 from the VDA Statistic
Share of Vehicles on Hand 7/1/1970 Classified according to Cubic Capacity (KBA)

No.	Vehicle Key No.	Cubic Capacity	Production		Production Share of the Class
			Share 1969 %	Share 1970 %	
	Share of Class		2,76	3,06	14,00
[illegible]	[illegible]	Capacity 0,[illegible] to 0,[illegible] ltr.	0,64	0,71	0,28
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
Total Vehicles Tested %			0,64	[illegible],71	[illegible]
Percent share of Class Tested			[illegible]	23,2[illegible]	[illegible]
	Share of Class				
3	[illegible]	Capacity 1,00 to 1,99 ltr.	2,23	1,13	,07
[illegible]	[illegible]3		20,16	[illegible],20	6,43
4a	[illegible]3		-	-	7,4[illegible]
5	[illegible]		1,24	1,35	0,16
6	127		9,76	8,98	[illegible],32
7	133		[illegible]	[illegible],01	0,17
8	134		3,48	2,23	,83
9	[illegible]		[illegible]	[illegible],84	[illegible],28
[illegible]	[illegible]		[illegible]	[illegible]	,18
[illegible]	[illegible]		[illegible]	[illegible]	0,67
[illegible]2	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible],20	[illegible],37	[illegible]
[illegible]	[illegible]			[illegible]	0,23
[illegible]	[illegible]		[illegible]	[illegible]	0,04
Total of Vehicles Tested %			34,14	27,[illegible]	[illegible]2,5[illegible] 29,9[illegible]
% Share of Class Tested			86,93	85,01	24,02 57,36

* The values of 103 are representative also for values in parentheses

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Tabelle 6
Blatt 2

Nr.	Vehicle Key No.	Class	Production Share 1969 %	Production Share 1970 %	Share of cl inventory 7/1/70	Share for 1971 estimate
	Share of Class	4	32,10	43,9[illegible]	21,00	
16	101	Capacity 1,50 bis 1,99 ltr.	0,40	0,42	0,18	
17	102		0,20	0,1[illegible]	0,01	
18	104		2,96	2,8[illegible]	1,64	
19	105		1,07	0,50	0,31	
20	111			0,04	-	(0,[illegible])
21	112		0,16	0,12	0,04	
22	114		-	0,96	-	(0,46)
23	117		-	0,40	-	(0,19)
24	118		1,56	1,21	0,33	
25	120		-	0,48	-	(0,93)
26	129*		5,55	5,83	2,07	
27	135		1,[illegible]7	1,47	0,40	
28	141		J	J	0,36	
29	144		2,05	2,88	0,09	
30	145		-	(0,28)1)	-	(0,29)
31	146		1,20	1,56	0,30	
32	147		-	0,38	-	(0,30)
33	148		J	J	0,02	
34	150		J	J	0,03	
35	152		J	J	0,68	
36	(125)2)		0,84	0,93	(1,07)2)	
37	(126)2)		0,79	0,84	(0,56)2)	
Total of Vehicles Tested %			18,48	21,00	6,46 (8,09)	(1,98)
% Share of Class Tested			57,57	47,78	30,76 (38,52)	

* = This value is derived from class 6 but also representative for the share of passenger cars in class 3

J = imported vehicles

1)= Share of Production 1971 (1970 not yet in production)

2)= The values of 125 and 126 are representative also for values in parentheses could be determined and are summarized in the following table:

Class	Cubic Capacity	Percentage %	Share in 1000 of Total
1	0.00 bis 0.99 ltr.	4.86	95
2	1.0 - 1.49 ltr.	24.02 (57.36)	1750 (4190)
3	1.5 - 1.99 ltr.	30.76 (38.52)	895 (1130)
4	2.0 - 2.99 ltr.	36.00	270
5	>3.0	8.75	2
6	Kombi	22.80	232

( ) Numbers in parentheses indicate that the measured values are valid also for similar types of the same motor construction in other categories.

Out of a total number of passenger cars and station wagons as of July 1, 1970 of 13.941 million vehicles a total of 3.244 or (5,919) million vehicles, i.e. 23.2 or (42.4)% were covered in this study.

The types were selected so as to consider the vehicles most frequently found in city traffic. They include also imported types of vehicles, especially from French and Italian manufacturers.

1.3 Tolerance Values, Inner Urban Traffic and Noise Maps

The tolerance values specified by regulations are again and again taken as standard for the evaluation of the inner city traffic, their reduction is demanded from many sides (18) and at the same time discrepancies are being pointed out that exist between the tolerance emission values specified by regulations for the various types of vehicles on the one hand, and those required by physiologists, medical doctors and organizations for the battle against noise on the other (15, 17, 6, 35).

From extensive measurements in street traffic under the most divergent road and building conditions and with different traffic loads, noise maps have been constructed for many cities that give realistic pictures of actual immission values (19, 8, 44, 45).

But even if such surveys cover the number and types of the passing vehicles, the driving speed of the individual car, the choice of gear by the driver and the number of motor revolutions remain to be considered. These parameters determine, however, in the last analysis, the urban traffic noise level at any given instant. From the measured immission values it is possible to determine whether the equivalent continuous noise level L_{eq} (41) at a given place agrees with the values specified by the guide lines (e.g. VDI 2058, folio 1), but it cannot be stated whether and by what means level reductions are possible, either on the noisy vehicles of the neighboring buildings (36, 37).

1.4 Extended Programs to Measure Outdoor Noise; Organization and Utility

For these reasons the testing program for emission values that is used in the type examinations, was considerably extended in the present study. Through various special testing programs it was possible to cover nearly all noises that are generated in the normal course of driving, during standing, during acceleration and braking, as well as during driving at constant speed. The effect of a "sporty" handling of the car were also determined for different noise generating processes (11, 12).

In this way results and evidences could be obtained by simple test methods which are otherwise only obtainable by more demanding recording methods.

The extended test program for outdoor noises of passenger cars and trucks is appended as layout 1.

The program had to be modified for the category of Mofas, Mopeds and motorcycles. It is appended as layout 2. In the course of this investigation it became evident that particularly for city traffic starting and accelerating in low gearcan be decisive.

For all tests the measuring distance specified for the type examination of 7.5 m ± 0.2m or the measuring distance specified for idling noise of 7 m behind or to the side of the vehicle was observed. The same for the measuring height of 1.2 ± 0.1 m of the microphone so that all values are comparable. This has the advantage that noises during different operating conditions can be represented in direct comparison with the value for type examinations. Thus effects arising from individual handling of vehicles, such as loud or quiet closing of doors, normal or "sporty" starts, or the choice of the gear used in city driving, become clearly evident.

In analogy to the European driving cycle for exhaust emission (46) (EFZ), noise levels were assigned to driving conditions that resemble those specified in the EFZ so that, making certain adjustments, a percentage distribution of noise levels in city traffic is feasible (for details see table 7).

For the categories of trucks and cycles the percentage contribution was modified so that they would correspond to the characteristics of these groups of vehicles.

In addition, the contribution of the rolling noise and the motor noise level, partly also the intake and exhaust levels, were determined on measured type values. For a planning of meaningful immission protection measures a knowledge of the different partial noise levels and their exact determination is of decisive importance.

2. Execution

2.1 Extent of Measurements, Measuring Instruments and Tables

To determine emission values a total of 20 different bicycle types of domestic and foreign provenience were tested at the factory by the testing team of Heinrich Gillet KG according to the testing program represented in layout 2. They were: Mofas, Mopeds, light motorcycles and heavy motor cycles.

In the same way 5 trucks and buses below 3.5 t total weight, 22 trucks and buses above 3.5 t total weight (including 2 electrobuses) and 53 passenger cars and station wagons were tested. Testing program in layout 1.

Two precision sound level meters from Bruel & Kjaer type 2203 and 2204 were the instruments used. In all cases readings were made on curve A with the indicator set to "rapid", as present regulations demand.

In testing idling noises all measurements were made twice, namely, once at a distance of 7 m behind the vehicle, i.e. in most cases in the direction of the exhaust and once at a distance of 7 m to the side, in the middle of the vehicle axis. This test point is specified as obligatory in the EG guide line.

Furthermore it was observed that noise generation during acceleration

Table 7

Evaluation of Operating Modes by the EFZ for Exhaustgas Emissions and Noise Levels

Determined from Layout 1 and 2

Grade	Gear	Speed km/h	Accelerat. m/s²	Time in s single value	Time in s sum	idling	start	1/3 phas.	decel. 32 km/h	const. speed 50 km/h
1	0	0	0	11	11	11				
2	1	0-15	+ 1,04	4	15		4			
3	1	15	0	8	23				8	
4	1	15-10	- 0,69	2	25				2	
5	K/1	10-0	- 0,92	3	28				3	
6	0	0	0	21	49	21				
7	1	0-15	+ 0,83	5	54		5			
8	K	-	-	2	56			2		
9	2	15-32	+ 0,94	5	61			5		
10	2	32	0	24	85				24	
11	2	32-10	- 0,69	8	93				8	
12	K/2	10-0	- 0,92	3	96				3	
13	0	0	0	21	117	21				
14	1	0-15	[illegible],83	5	122		5			
15	K	-		2	124			2		
16	2	15-35		9	133			9		
17	K			2	135				2	
18	3	35-50	0,52	8	143					8
19	3	50	0	12	155					12
20	3	50-35	- 0,52	8	163					8
21	3	35	0	13	176				13	
22	K	-	-	2	178				2	
23	2	35-10	- 0,99	7	185				7	
24	K/2	10-0	- 0,92	3	188				3	
25	0	0	0	7	195	7				
					195	60	14	19	75	29
					[illegible]	31	7	10	38	14 = 100%

K Shift to change gears
K/1 disengaged, then 1. gear
K/2 " " 2. "

To avoid introduction of several test procedures in Europe concerning exhaust gas emission that would have been very inconvenient for the European Automobile industry, the BPICA$^{1)}$ suggested a uniform European Test procedure. Since extensive studies of the operating modes of motor vehicles in city traffic had been done and national testing procedures had been developed in Germany and France, a common French-German testing cycle was to be elaborated first. England and Italy agreed to accept a common French-German testing procedure without carrying out measurements of their own.

Representatives of the UTAC$^{2)}$, of the VDA$^{3)}$ and of the Institute for Chemical Technology and Fuel Science of T.U.Clausthal elaborated a common plan for a driving cycle. This testing procedure called "European Driving Cycle" (EFZ) consists of three parts separated by idling phases. The characteristic tri-partite structure of the program, as well as the first two parts had been taken over essentially from the German driving cycle. In order to facilitate simpler operation on the test ground for rolling conditions the third part was simplified and abbreviated so that the whole test lasts 195 sec.

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The maximal speed of 50 km/hr for constant driving in 3. gear and the time fraction for idling of 31 % of total driving time had also been taken from the DFZ (German driving cycle). The test procedure begins from a cold start of the test vehicle (temperature of the motor 20° C. The driving program is repeated 4 times and lasts thus 13 minutes. The individual operating modes of the driving program are summarized in the above table.

The plan for the European driving cycle was submitted to the GRPA[4] who suggested the acceptance of the test procedure by the individual national governments.

---

[1] BPICA: Permanent International Bureau of Automobile builders

[2] UTAC: Technical Association , Automobile, Cycle and Motorcycle

[3] VDA: Union of the Automobile Industry

[4] GRPA: Environmental Protection Agency

is decisively influenced by the choice of the gear and the number of motor revolutions when the vehicle passes the test line. Therefore, operating and handling modes were plotted, in addition to the values for accelerating noises, so that the relation between certain emission values and certain effects that a sporty handling of the vehicle causes can be recognized (layout 3 and 4).

Noises at various constant driving speeds were compared to earlier reports and critically reexamined and in order to obtain comparable values, to speeds of 30 and 50 km/hr the gears were assigned that are actually normally used at these speeds in city driving (12, 29)

This does not exclude the possibility that due to different driving behavior the sporty driver might exceed the measured values whereas the normal driver may not even reach them. The tables of measured constant speeds also contain values for the corrsponding rolling levels, the difference between driving and rolling noise and indication of the gear used.

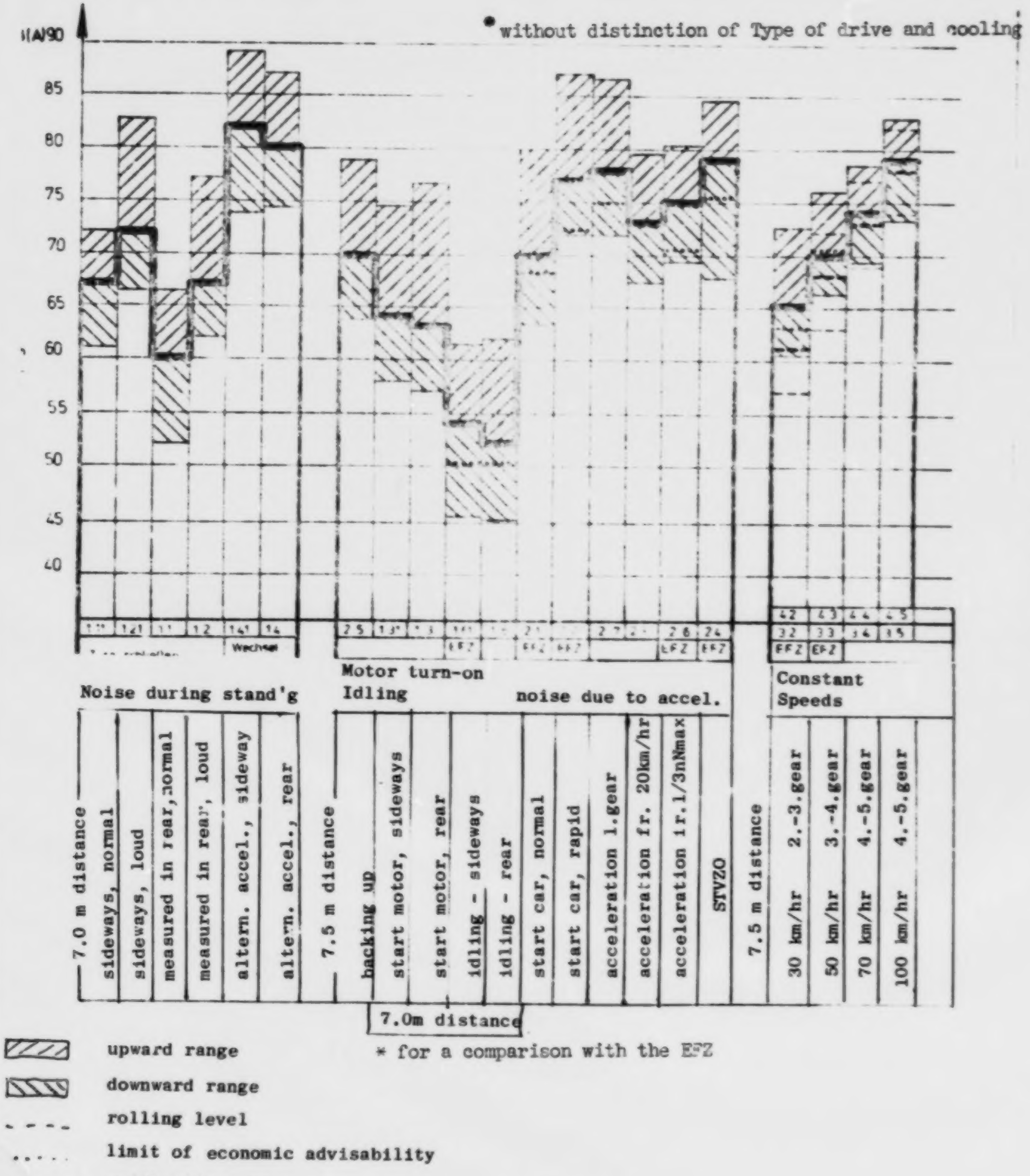
The over 16,000 individual measuring values were organized in tables which are being stored for further evaluations. In the interest of clarity they were not included in the long version of this report.

2.2 Representation of Emission Values of Different Types of Vehicles for Certain Operating Conditions according to DIN 45 636 and the Test Programs according to layout 1 and 2

All tabulated values were represented graphically and the three main groups: idling noises, acceleration noises and noises at constant driving speeds, were summarized separately for each category of vehicles (fig. 2 to fig.14).

Fig. 2
Passenger Cars,
General

Noise Emissions for Various Operating Modes in 7.0 m and 7.5 m distance



* for a comparison with the EFZ

Fig. 3
Passenger Cars
Standard Shift, air cooling

Noise Emissions for Various Operating Modes in 7.0 m and 7.5 m distance

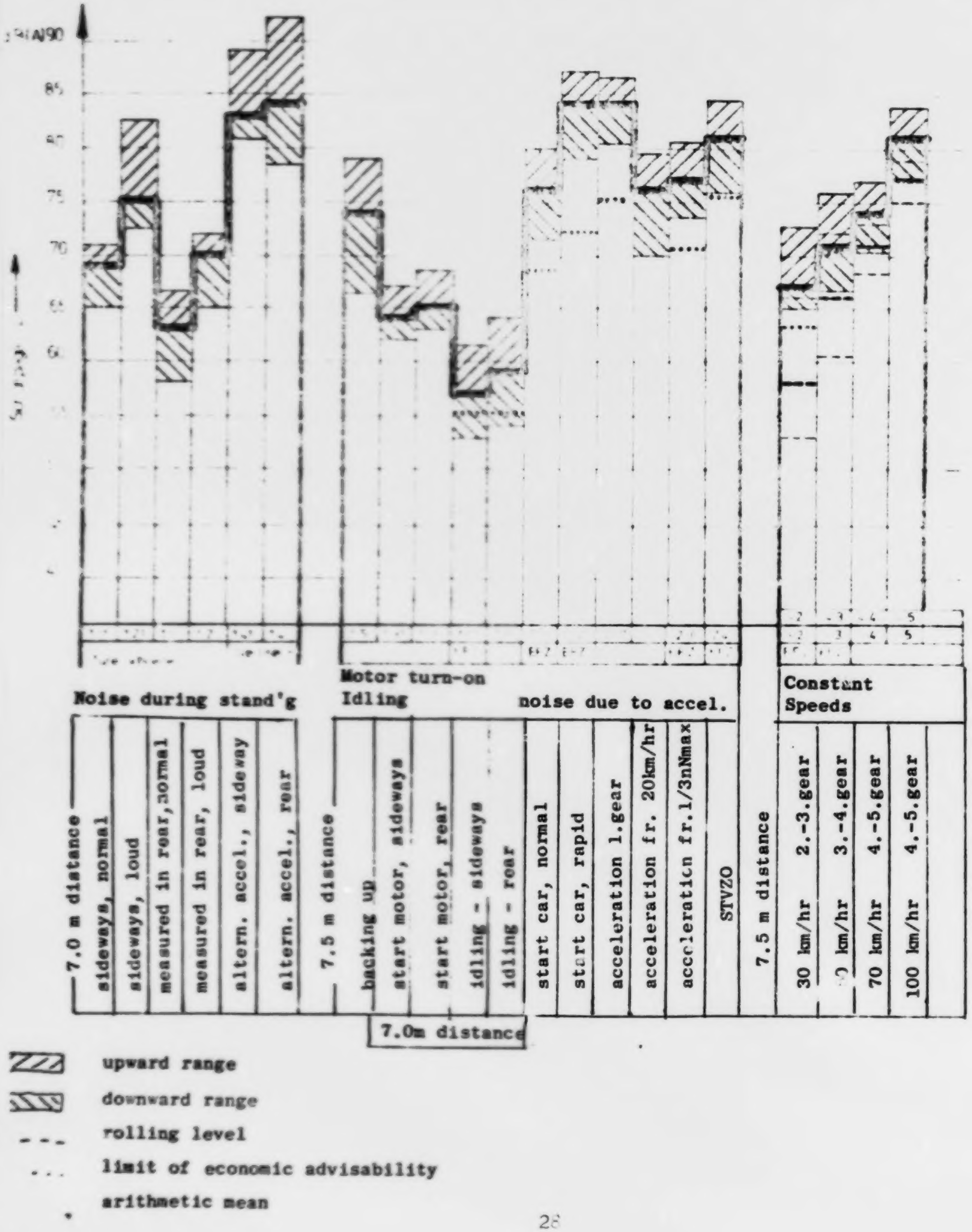


Fig. 4
Passenger Cars, Automatic Transmission, air cooling

Noise Emissions for Various Operating Modes in 7.0 m and 7.5 m distance

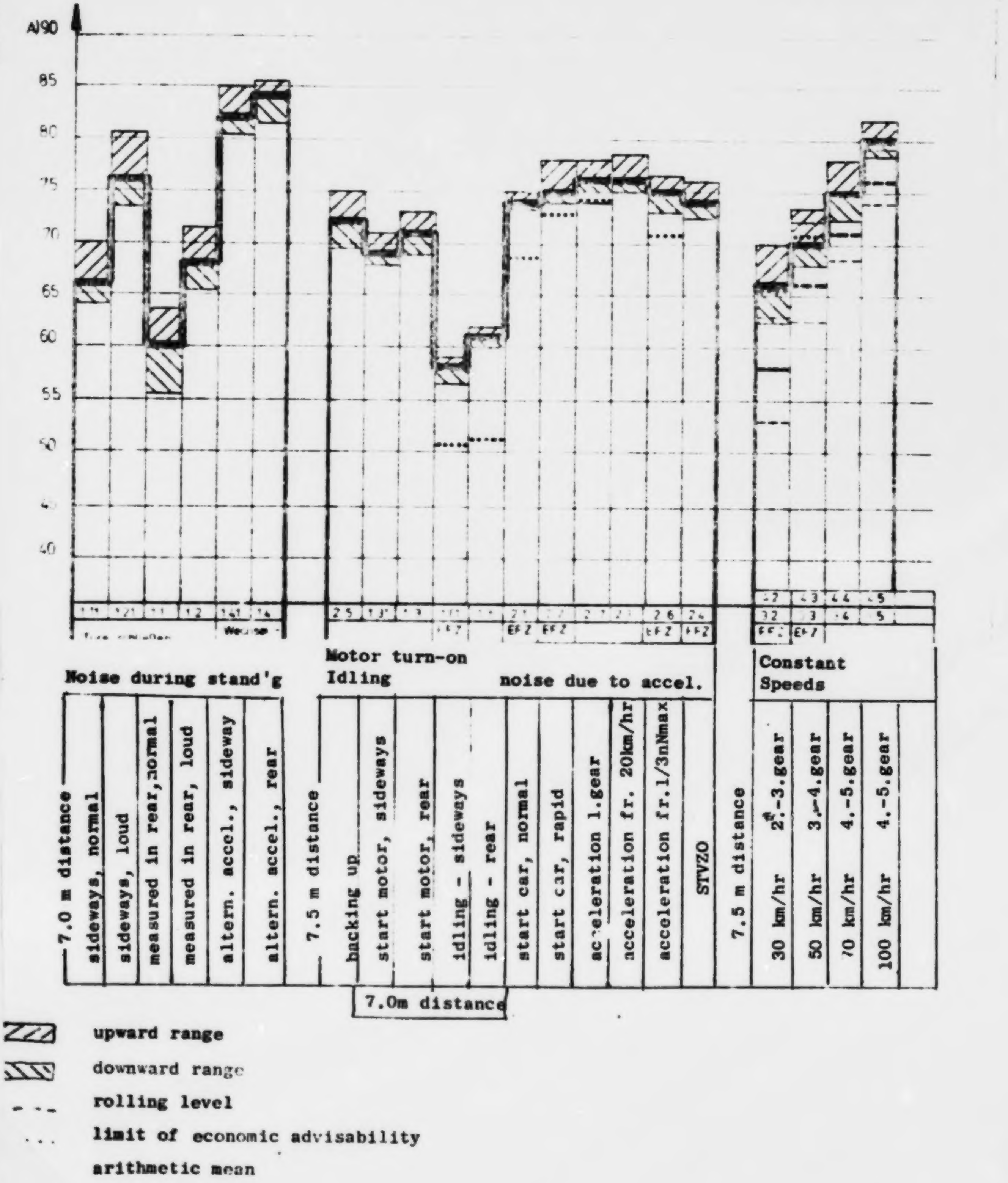


Fig. 5
Passenger Cars, Standard Shift
Water cooling

Noise Emissions for Various Operating Modes in 7.0 m and 7.5 m distance

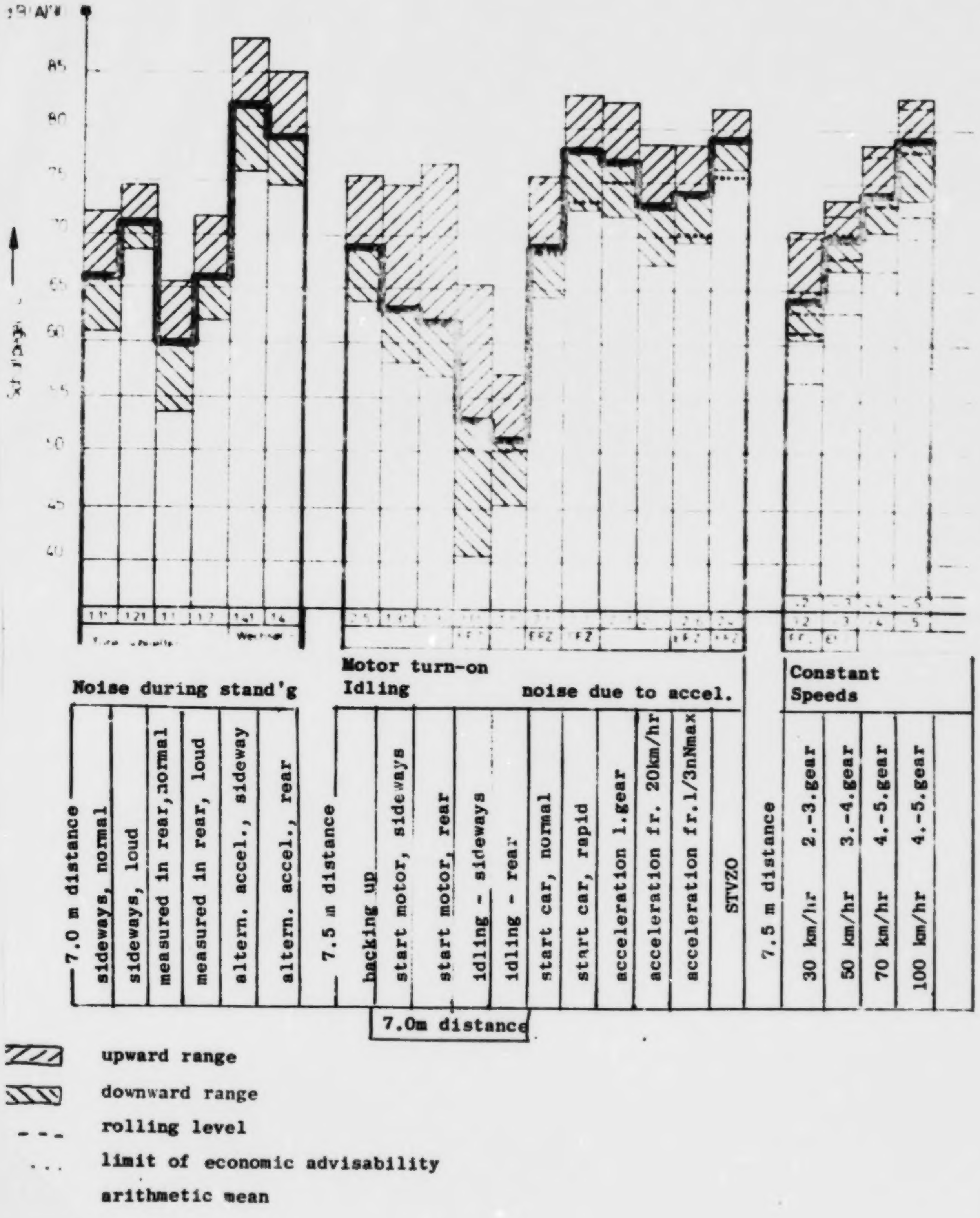


Fig. 6
Passenger Cars, Automatic
Transmission, water cooling

Noise Emissions for Various Operating Modes in 7.0 m and 7.5 m distance

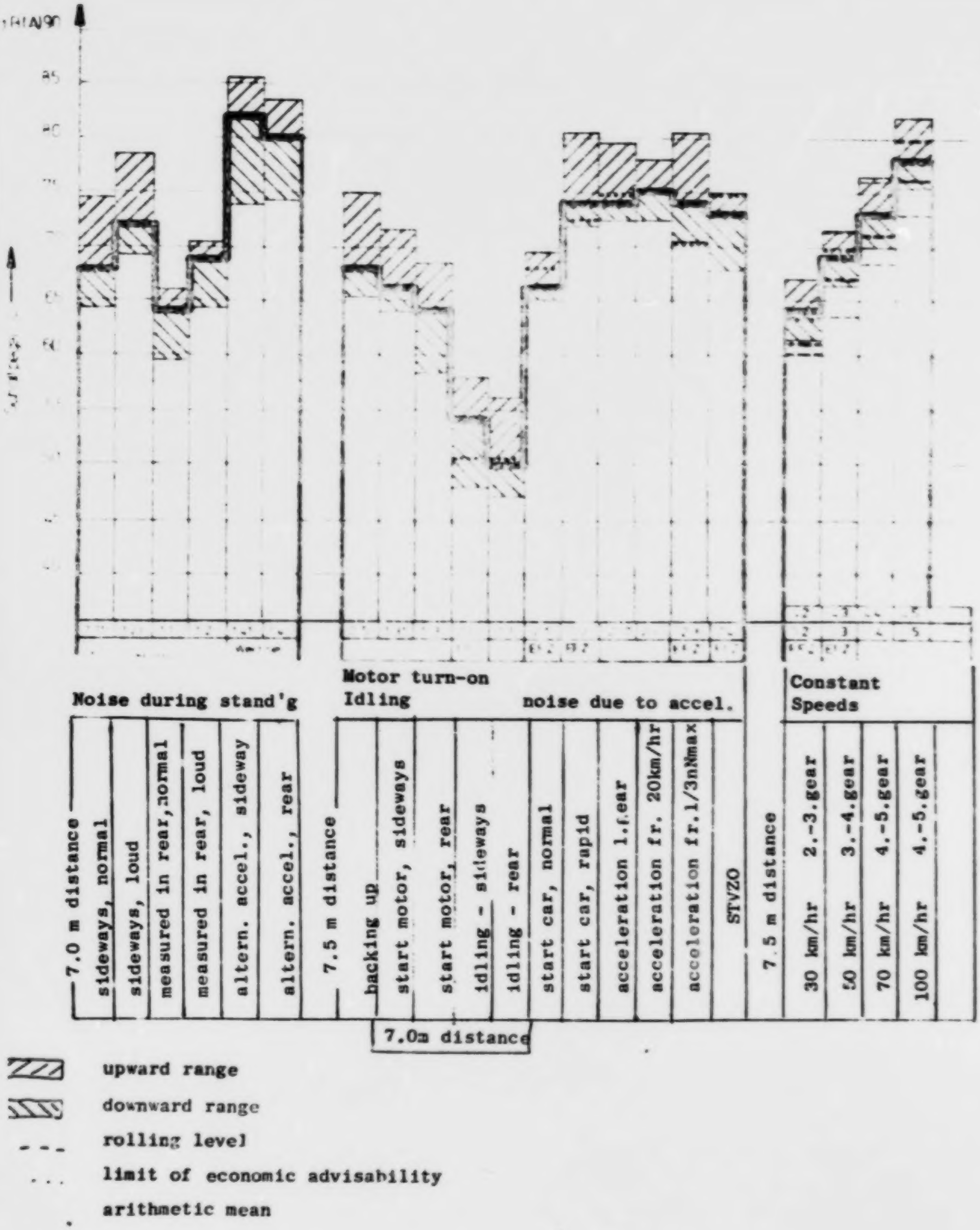


Fig. 7
Trucks below 3.5 t

Noise Emissions for Various Operating Modes in 7.0 m and 7.5 m distance

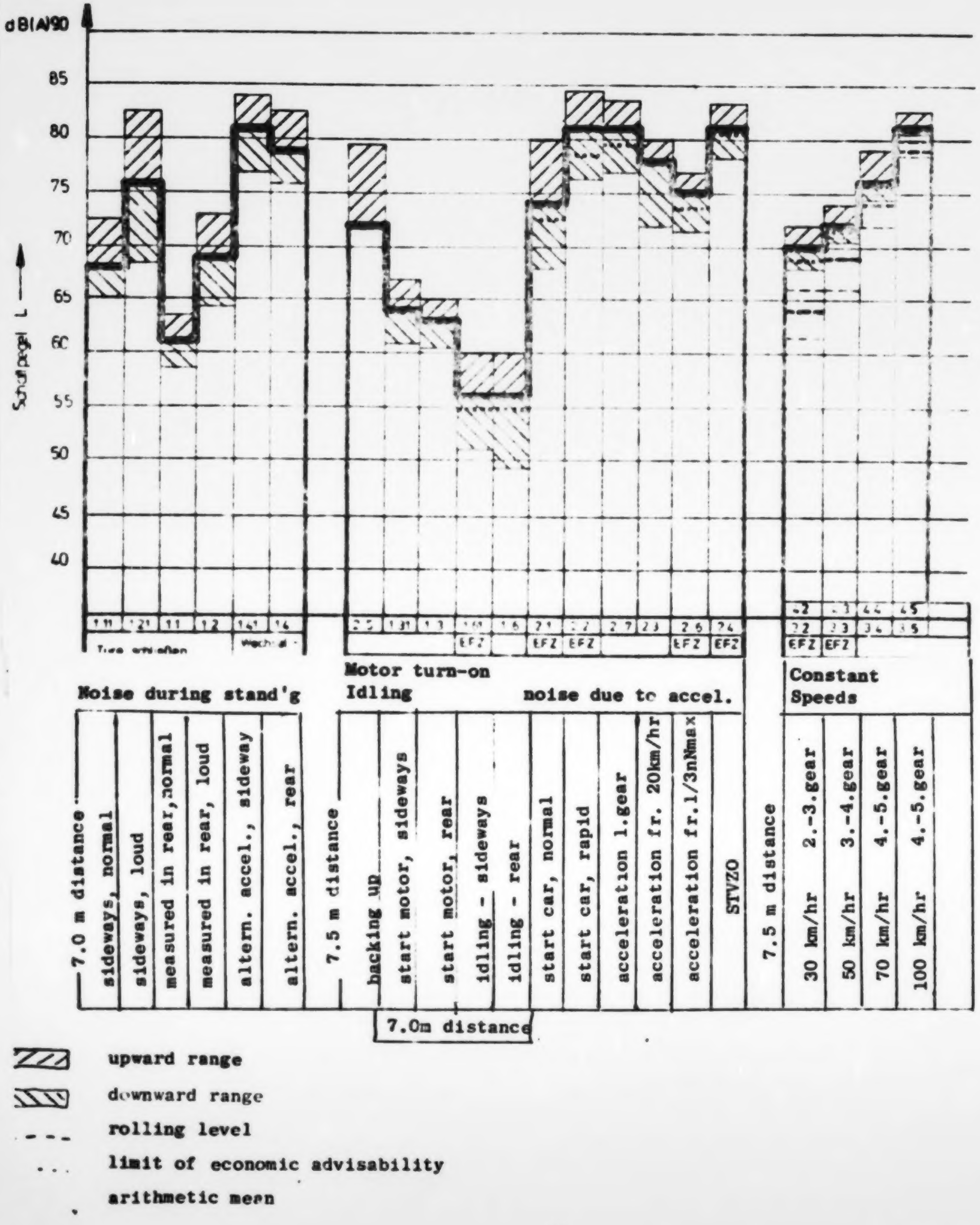


Fig. 8
Trucks above 3.5 t
Automatic Transmission

Noise Emissions for Various Operating Modes in 7.0 m and 7.5 m distance

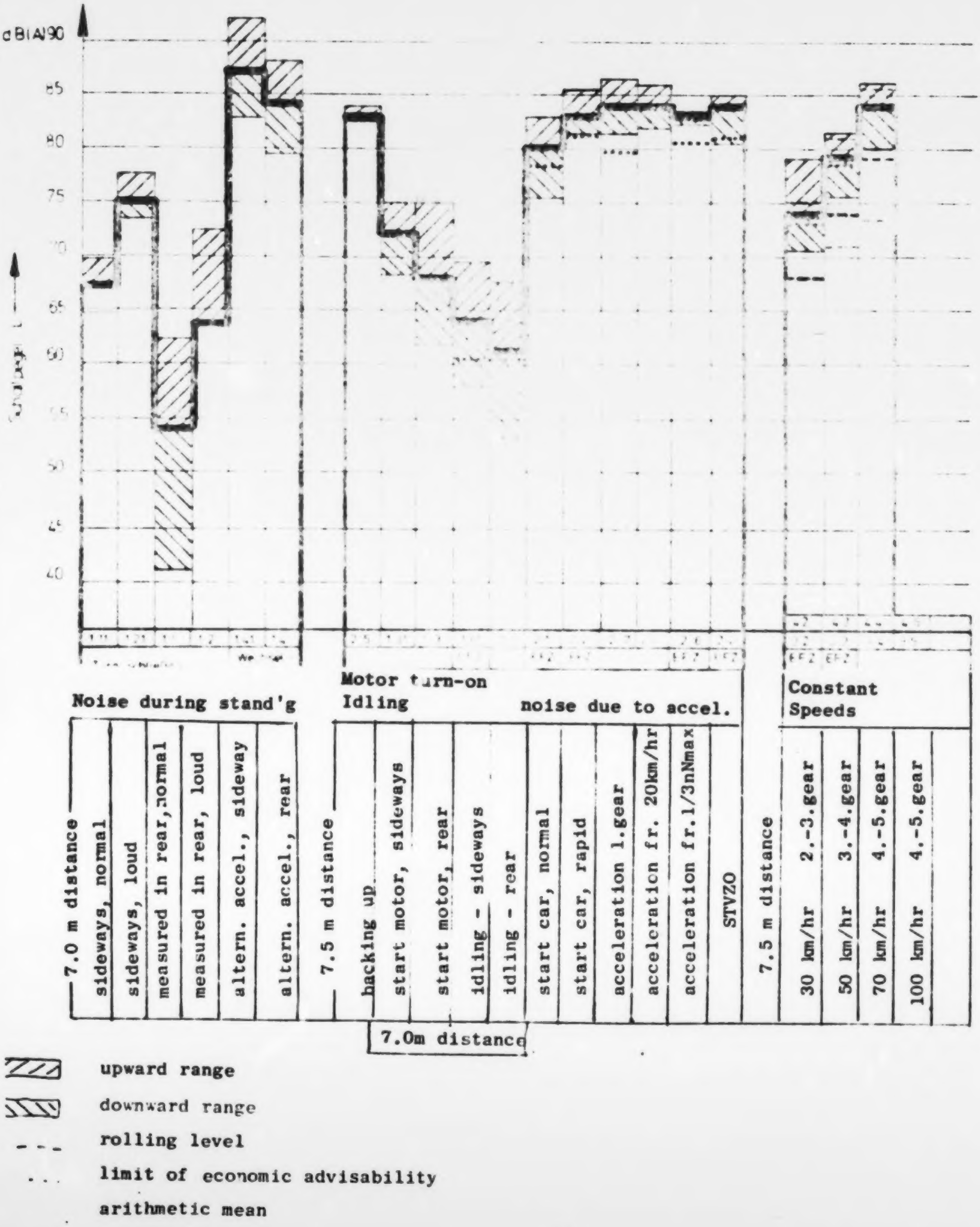


Fig. 9
Trucks above 3.5 t Standard
Transmission

Noise Emissions for Various Operating Modes in 7.0 m and 7.5 m distance

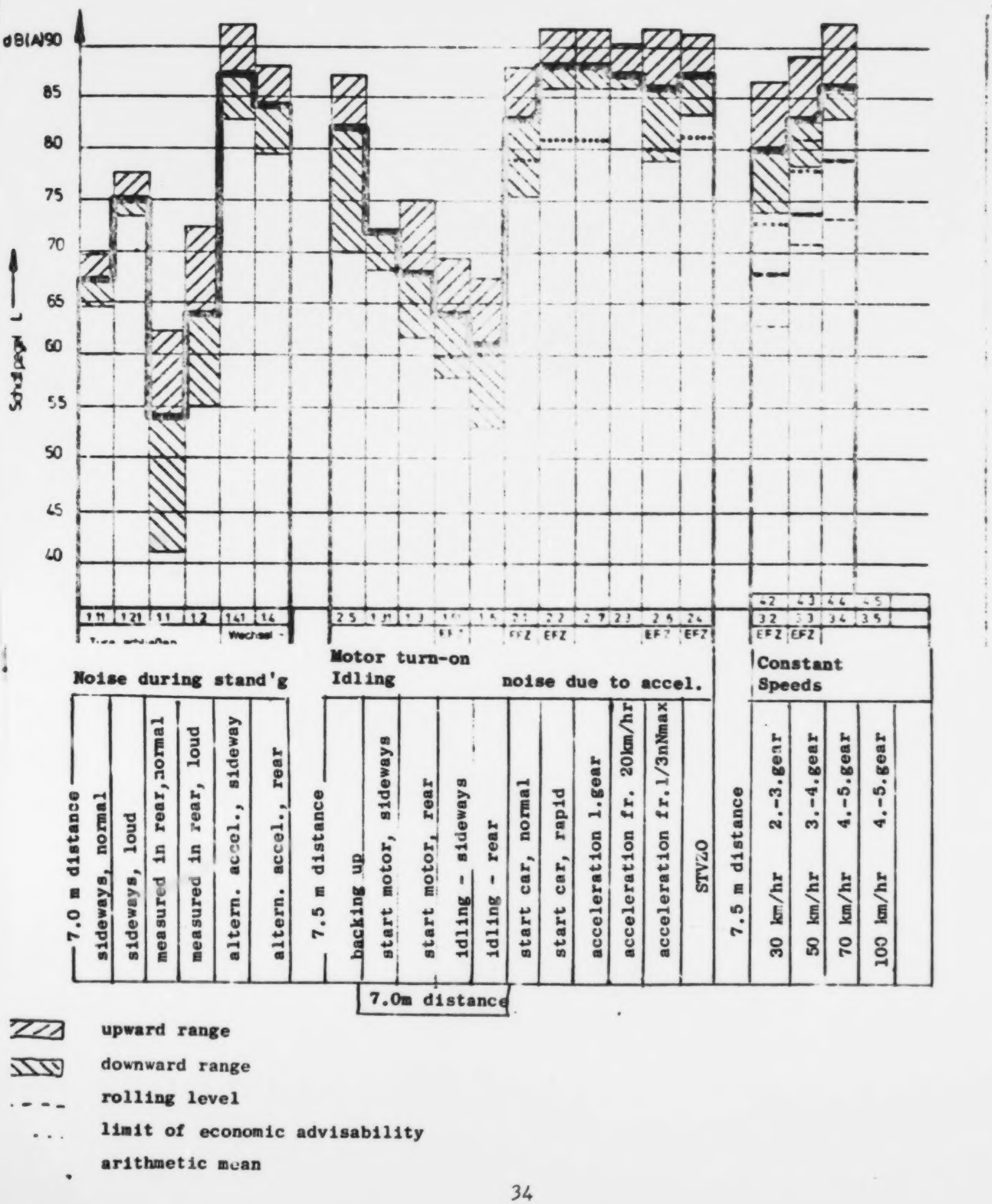
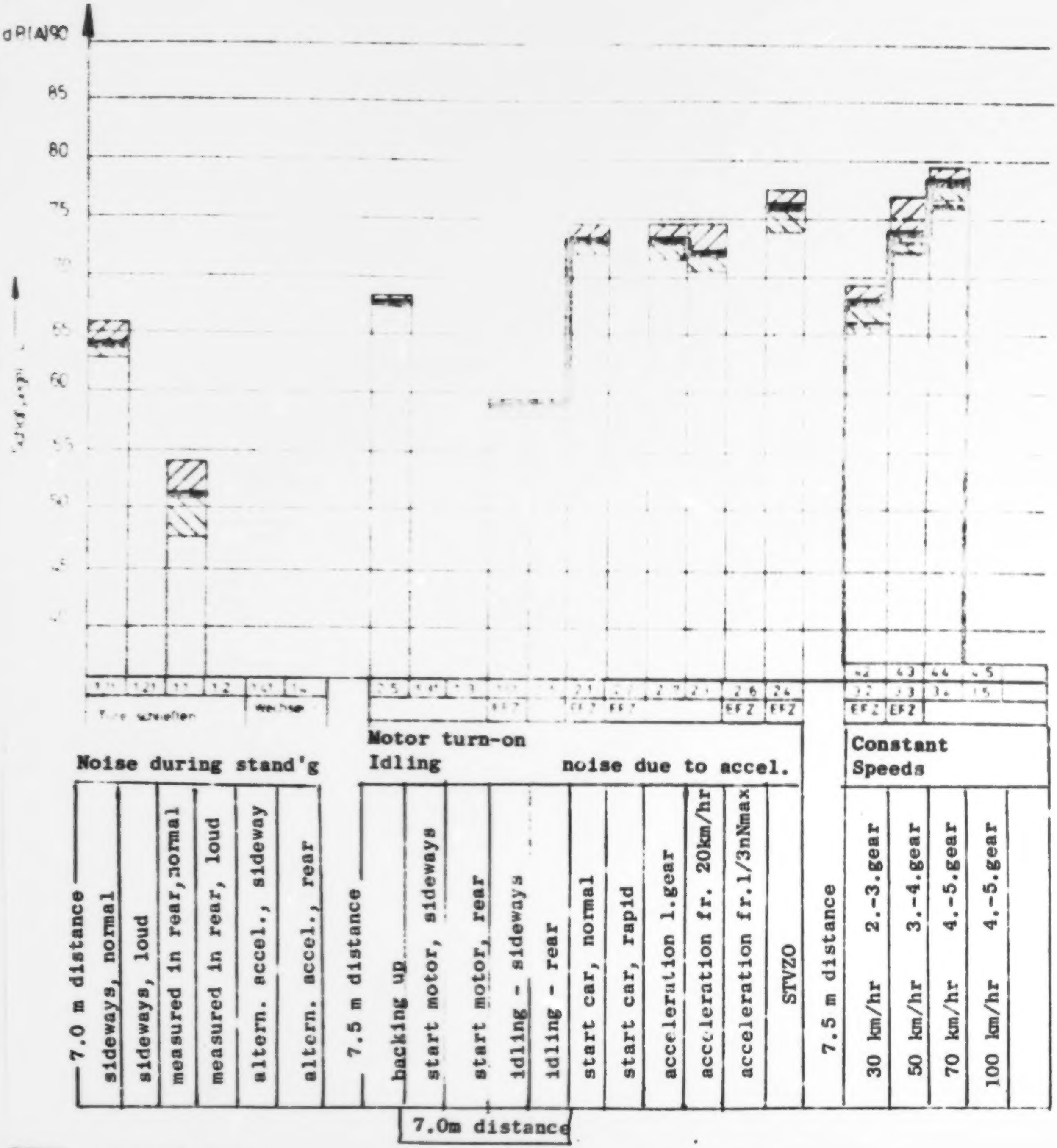


Fig. 10
Electric Vehicle

Noise Emissions for Various Operating Modes in 7.0 m and 7.5 m distance



▨ upward range

▧ downward range

– – – rolling level

. . . limit of economic advisability

arithmetic mean

At one glance the loudest and lowest levels, their relative height, and the corresponding operating conditions can be recognized. Each spread is given, also influences of handling, manipulation and road surface. The height of the driving level and its spread are marked.

2.2.1 Passanger Cars and Stationwagons

The results are given for all passenger cars together in fig. 2 and separately in figs. 3, 4, 5 and 6 because the type of cooling of the motor, the position of the motor and the type of gear influence the level differentially.

Fig.3 shows the results for cars with air-cooling and standard shift, fig. 4 air cooled cars with automatic shift, fig. 5 cars with water cooling and standard shift and fig. 6 water cooled cars with automatic shift.

2.2.2 Trucks and Buses, below 3.5 t Total Weight

Fig. 7 depicts the noise processes for this category of vehicles.

2.2.3 Trucks and Buses, above 3.5 t Total Weight

The noise levels are represented in fig. 8 in connection with the rolling levels. For trucks with automatic gear shift a separate evaluation is given in fig.9 Values for electro-buses are given in fig. 10.

2.2.4 Mopeds and Mofas

It must be noted that the StVZO distinguished between Mofas, tolerance value 70 dB(A) and Mopeds, tolerance value 73 dB(A). In fig. 11 noise generation for Mofas, including rolling noise, is represented. The same is represented for Mopeds in fig. 12.

2.2.5 Light Motorcycles and Motorcycles

Here too, it must be noted that light motorcycles and motorcycles represent two different categories, for which in the BRD tolerance values

Fig. 11
Type of Vehicle: Mofa

Noise Emissions for Various Operating Modes from 7.0m and 7.5m Distance

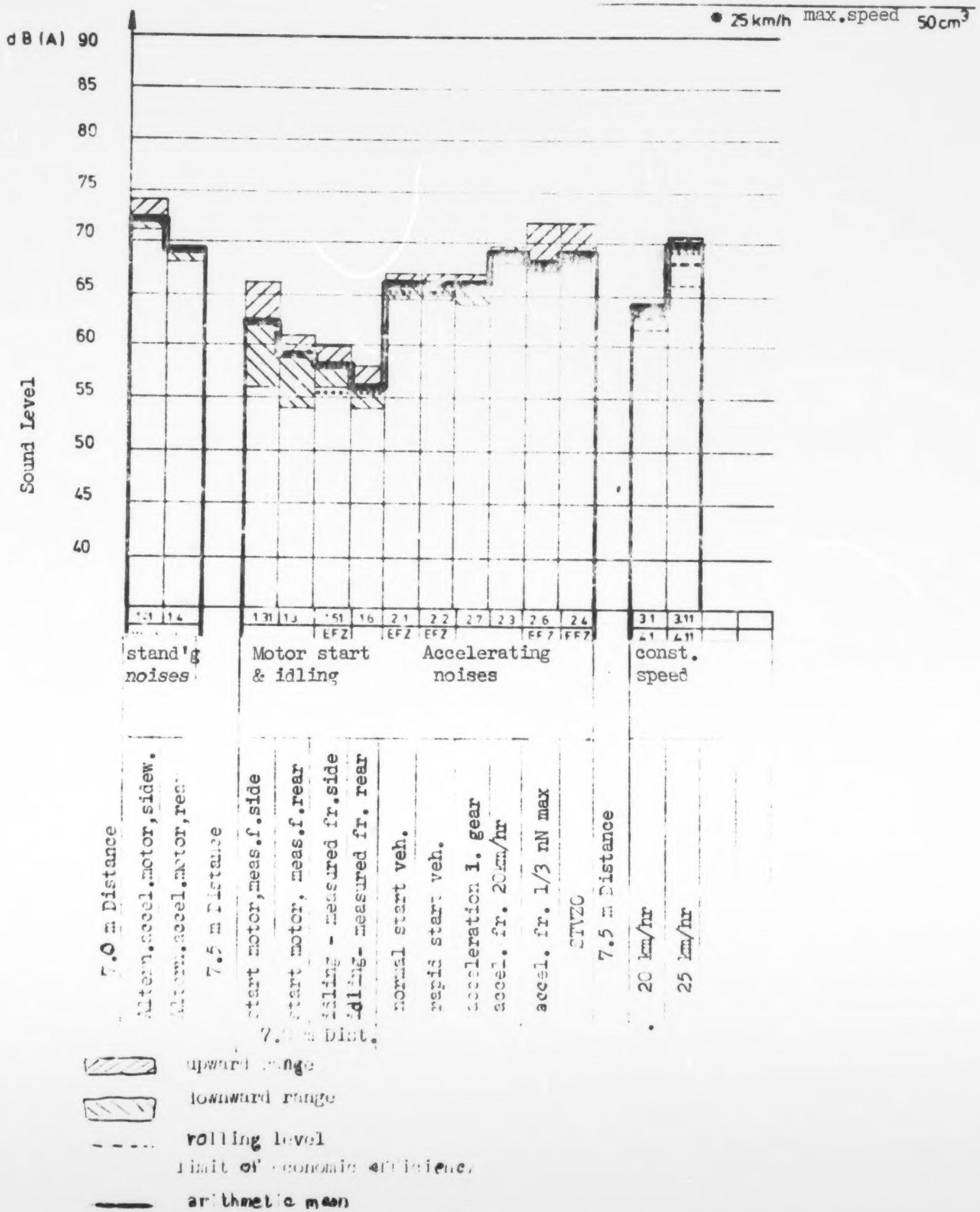


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Fig. 12
Type of vehicle: Moped

Noise Emissions for Various Operating Modes from 7.0m and 7.5m Distance

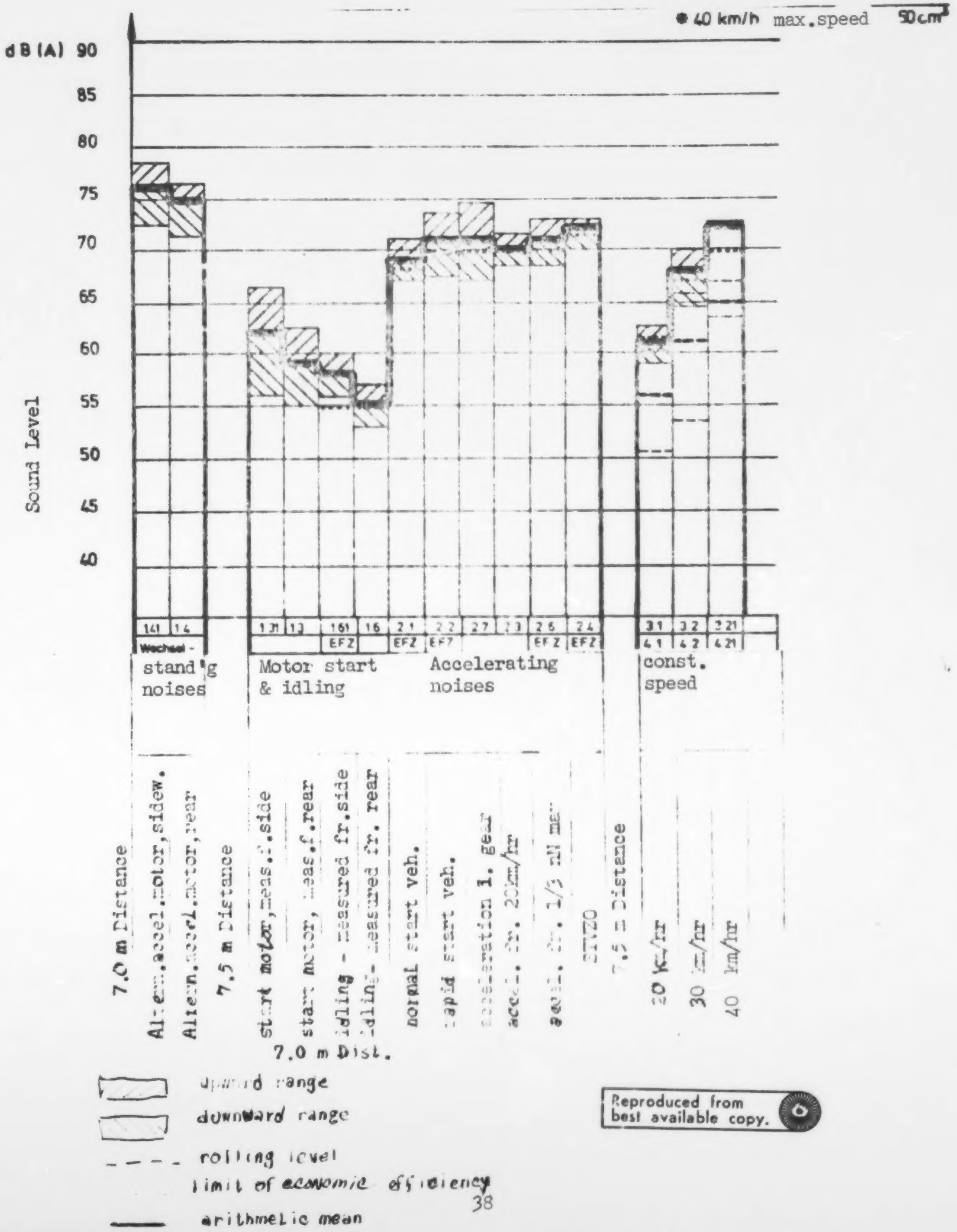

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Fig. 13
Type of vehicle: light
motorcycle

Noise Emissions for Various Operating Modes from 7.0m and 7.5m Distance

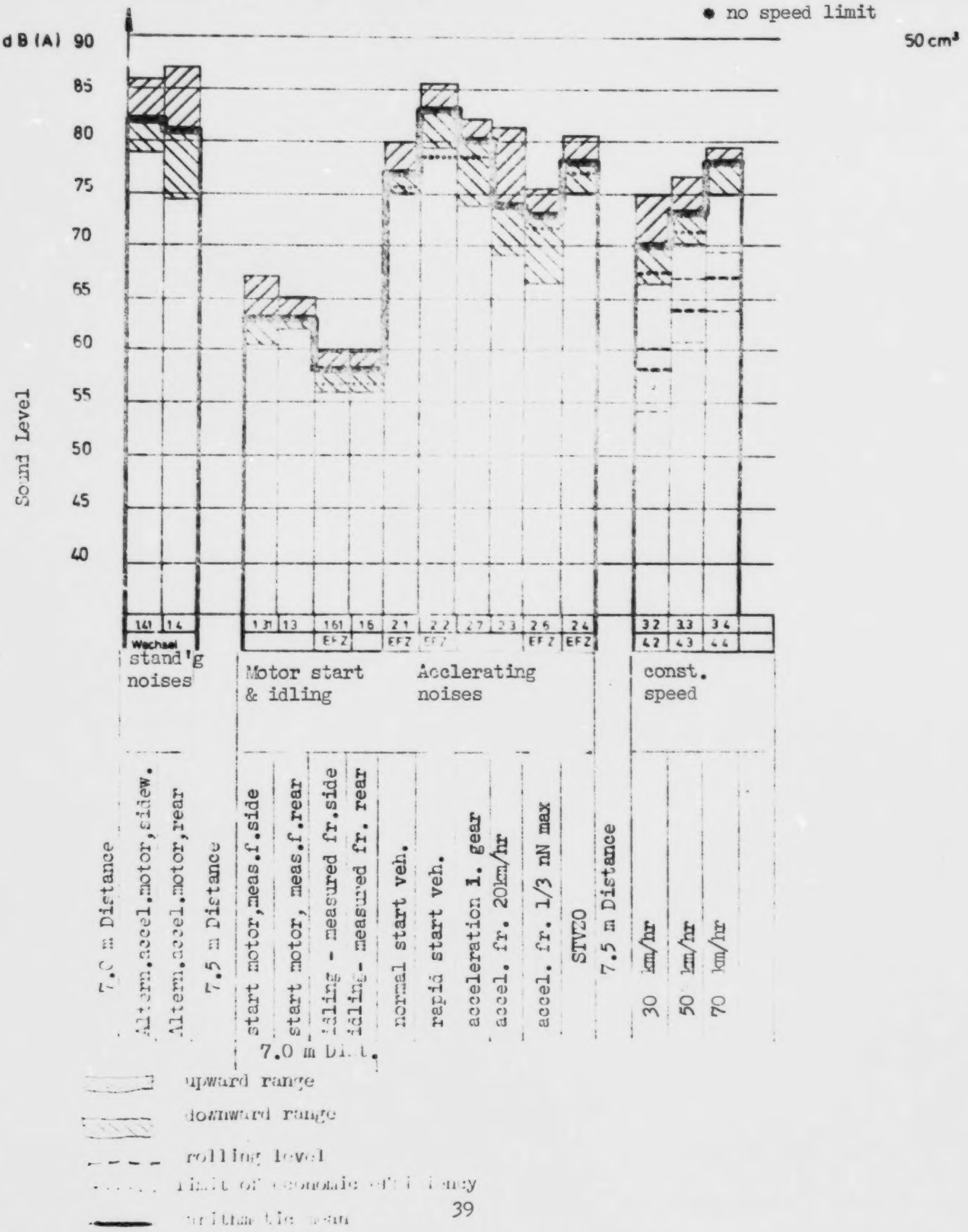


Fig. 14
Type of vehicle: Motorcycle

Noise Emissions for Various Operating Modes from 7.0m and 7.5m Distance

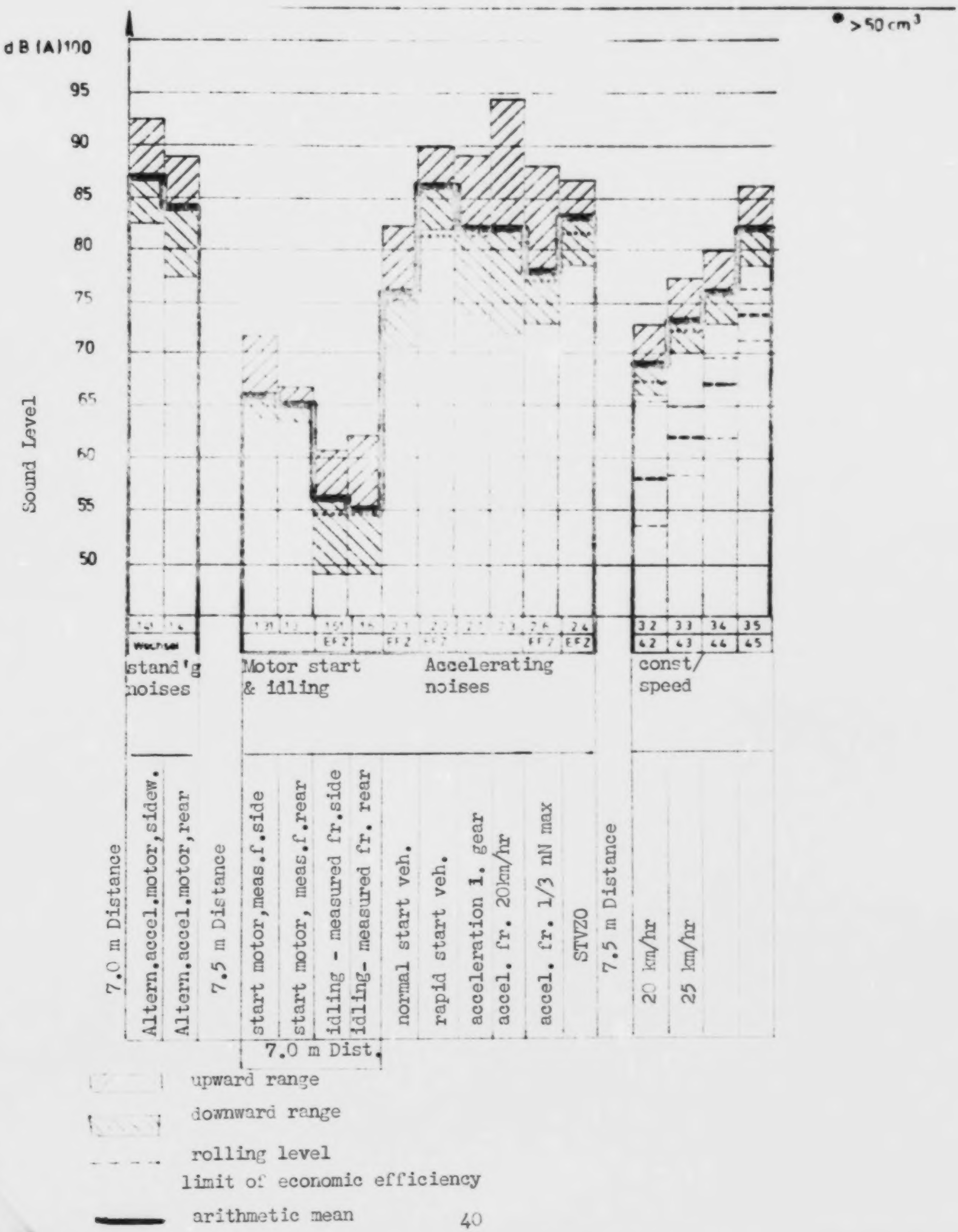
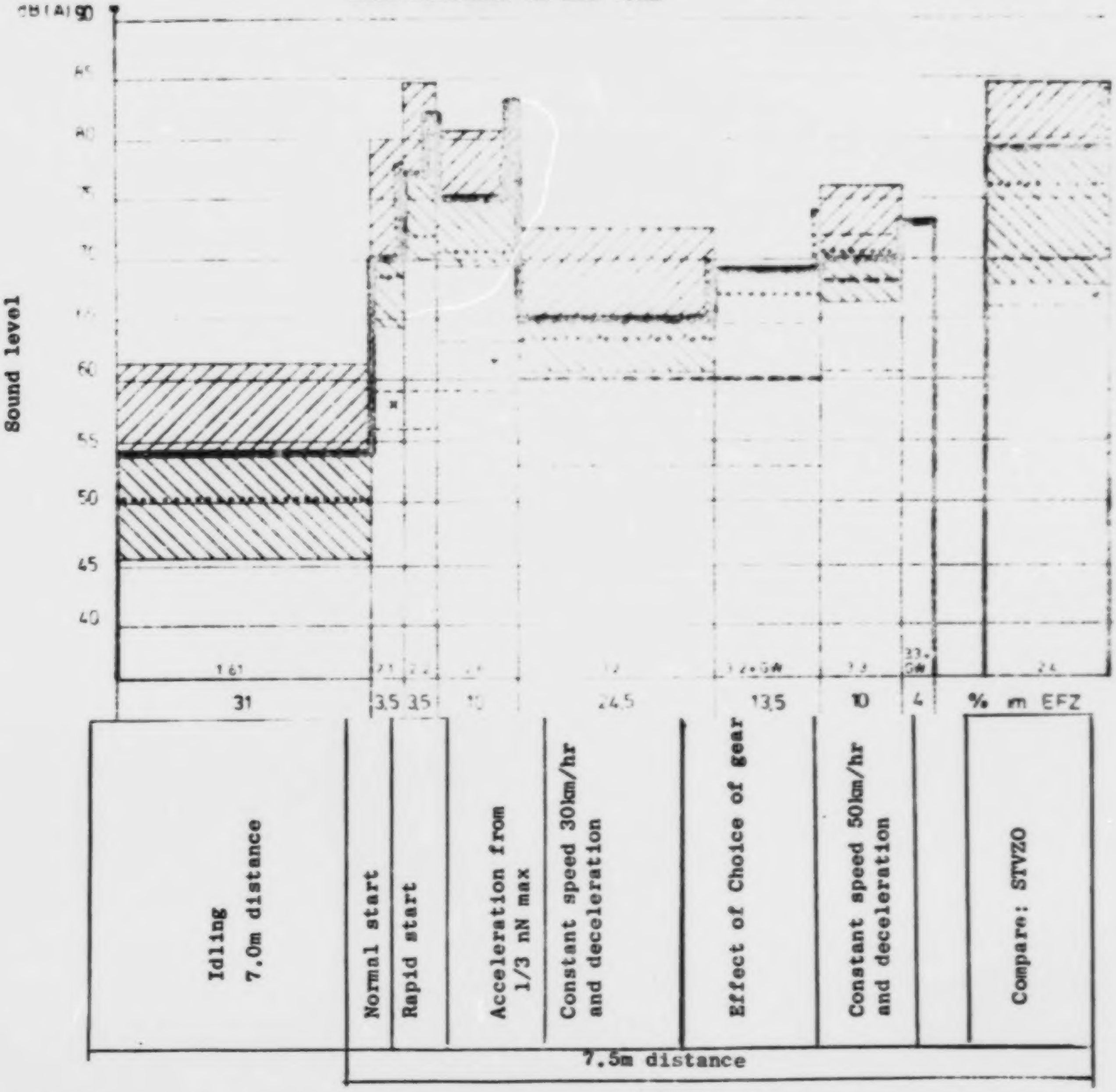


Fig. 15
Passenger Cars

Noise Emissions and Distribution in Urban Traffic from the European Driving Cycle for Exhaust Gas Emission (EFZ)

Test Distance 7m and 7.5m



▨ upward range

▧ downward range

☐ influence due to maneuvering[1])

▩ effect of road surface

- - - - - rolling level (accel.)

. . . . . . limit of economic advisability

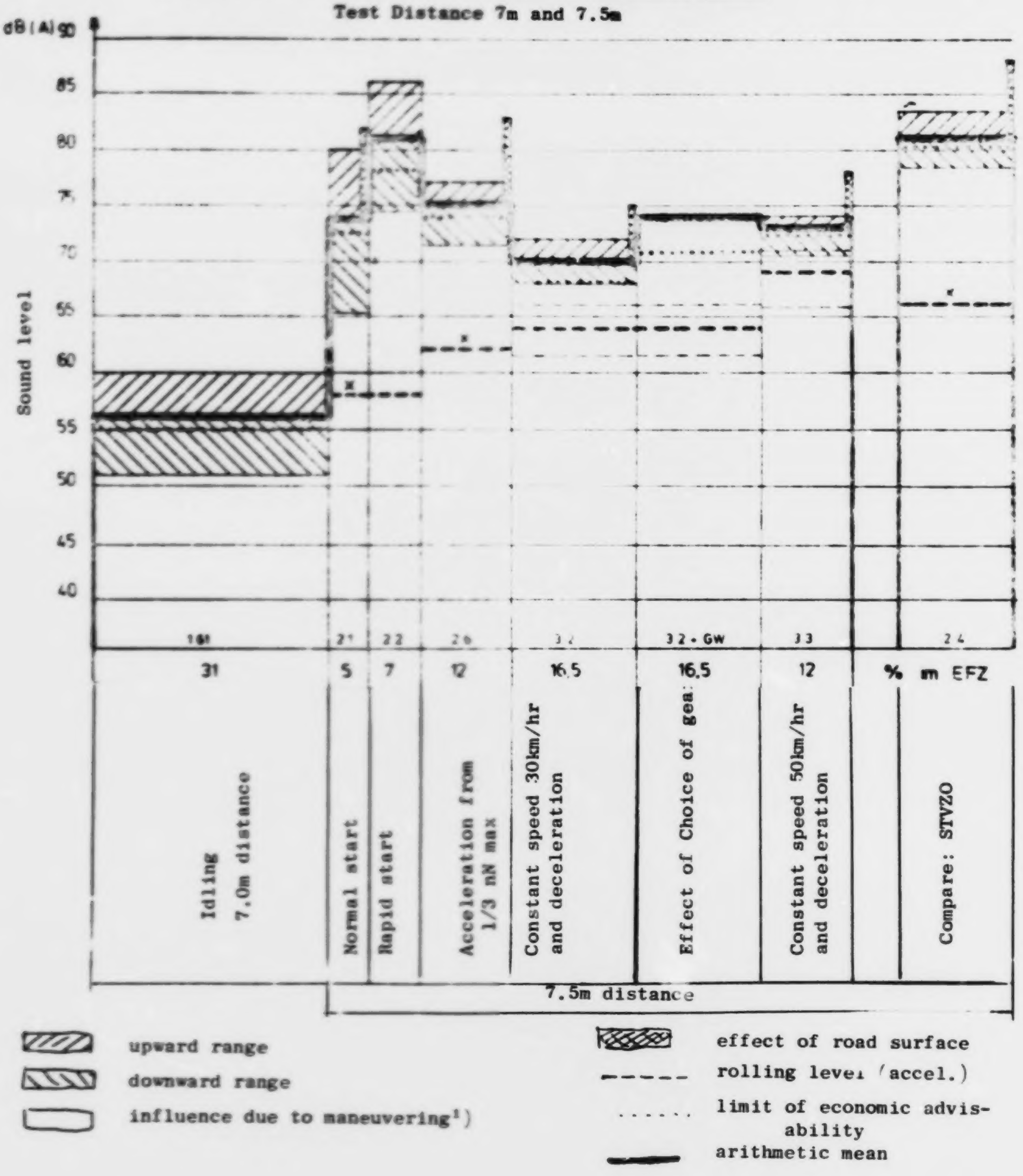
━━ arithmetic mean

[1]) not shown

Fig. 16
Trucks below 3.5 t

Noise Emissions and Distribution in Urban Traffic from the European Driving Cycle for Exhaust Gas Emission (EFZ)

Test Distance 7m and 7.5m



¹) not shown

Fig. 17
Trucks above 3.5 t

Noise Emissions and Distribution in Urban Traffic from the European Driving Cycle for Exhaust Gas Emission (EFZ)

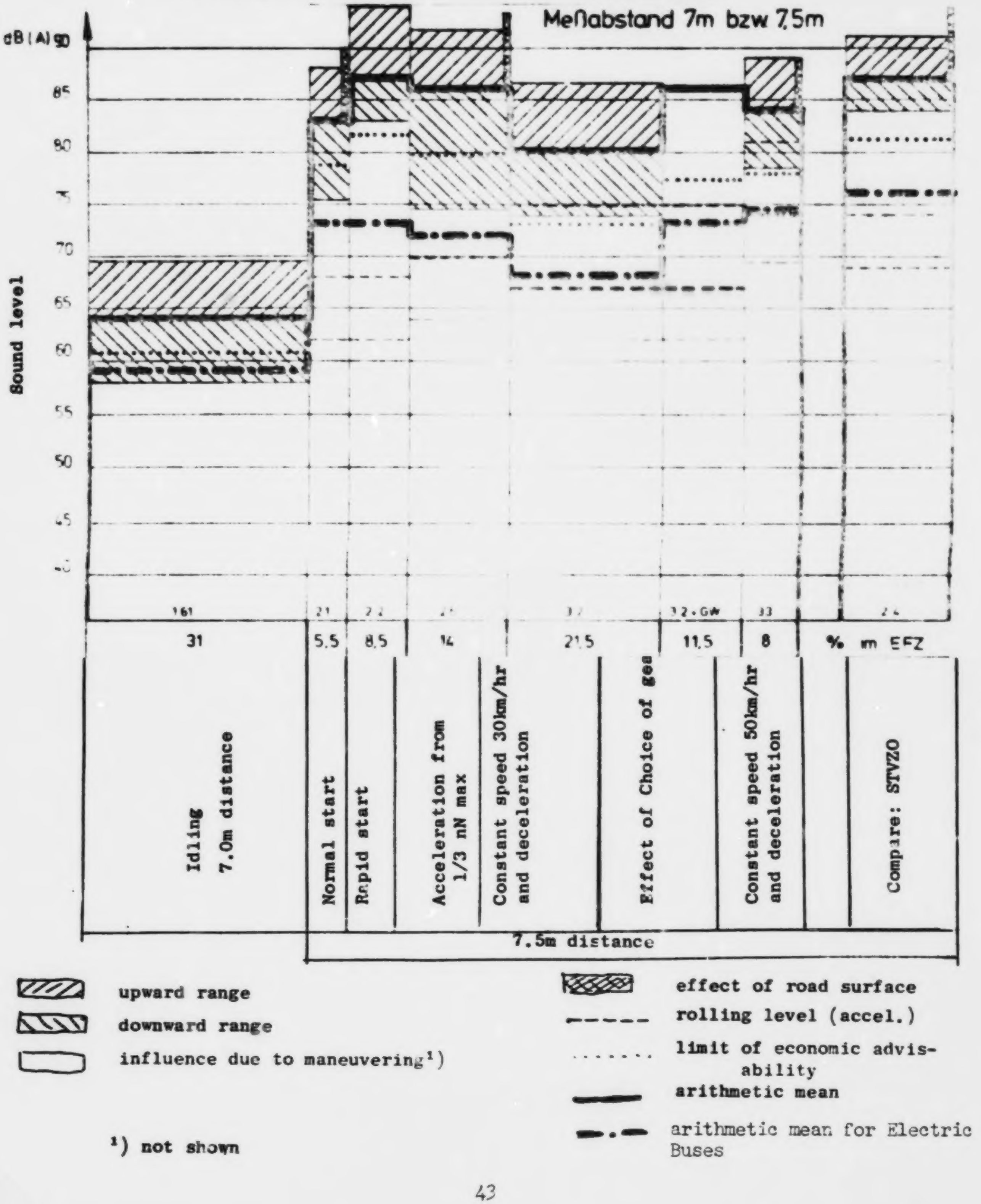
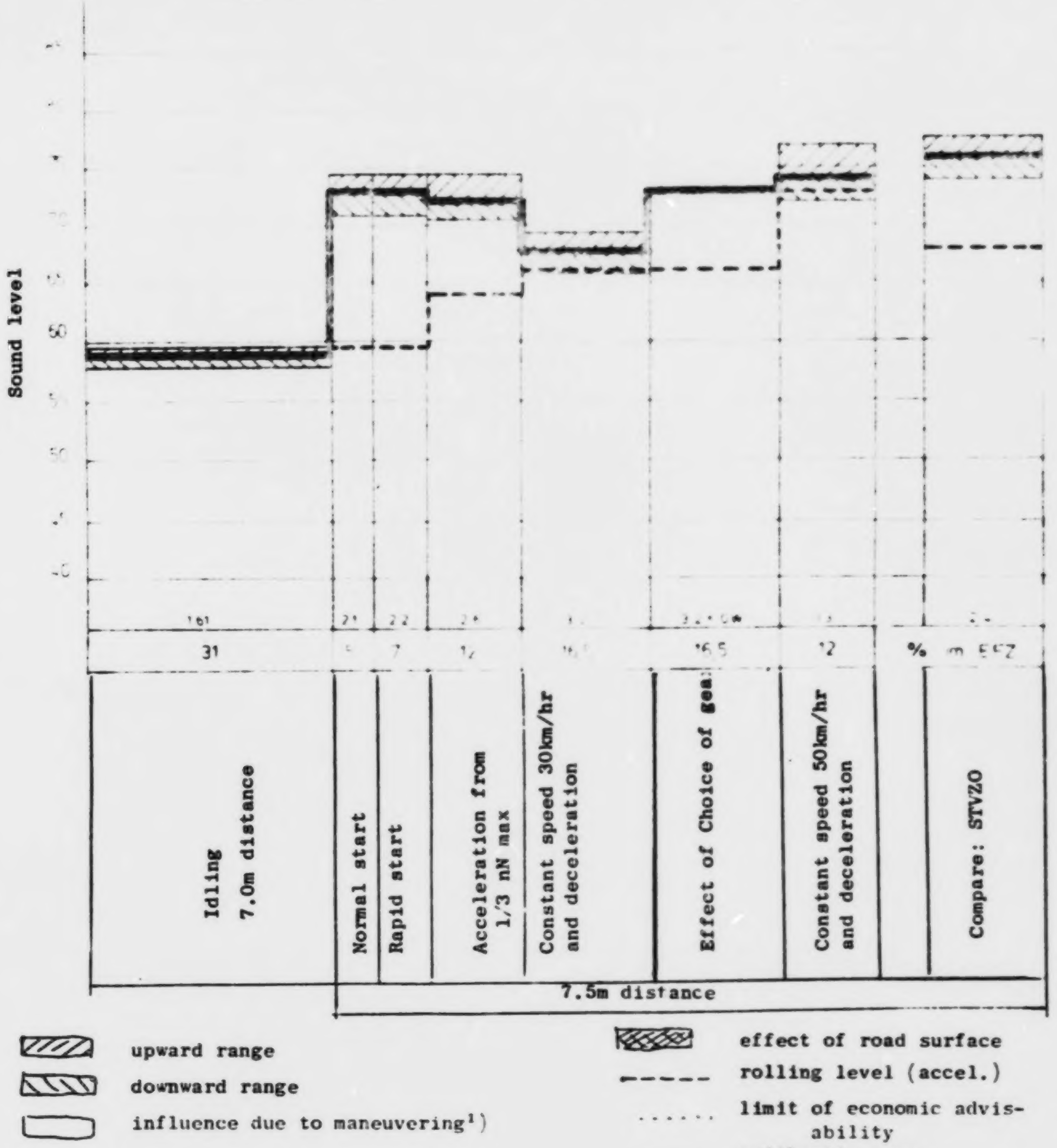


Fig. 18
Electric Buses

Noise Emissions and Distribution in Urban Traffic from the European Driving Cycle for Exhaust Gas Emission (EFZ)

Test Distance 7m and 7.5m

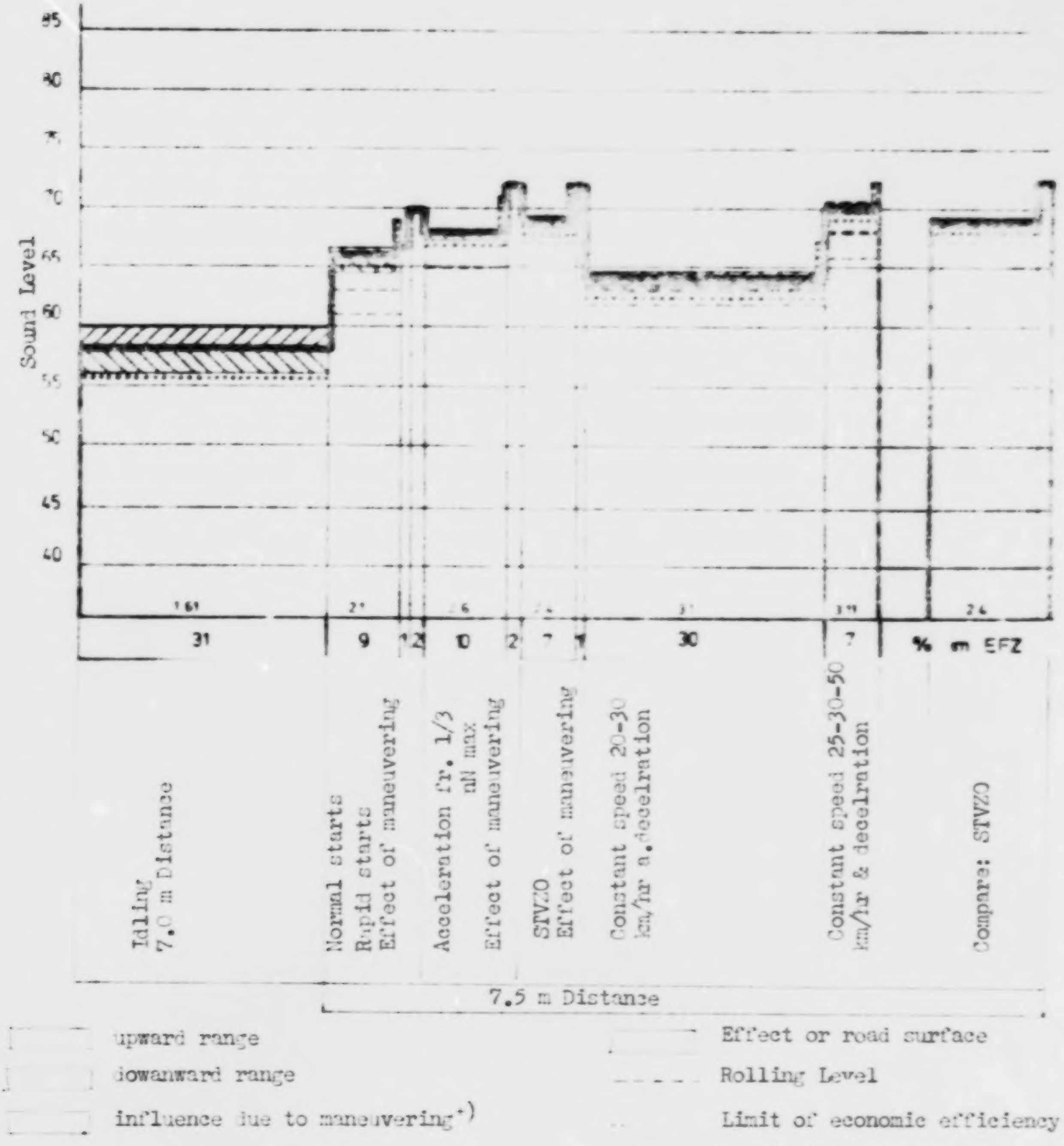


¹) not shown

Fig. 19
Type of vehicle: Mofa*

Noise Emission and Distribution in Urban Traffic from the European Driving Cycle for Exhaust Gas Emission (EFZ) Test Distance 7m and 7.5m

*25 km/hr max. speed

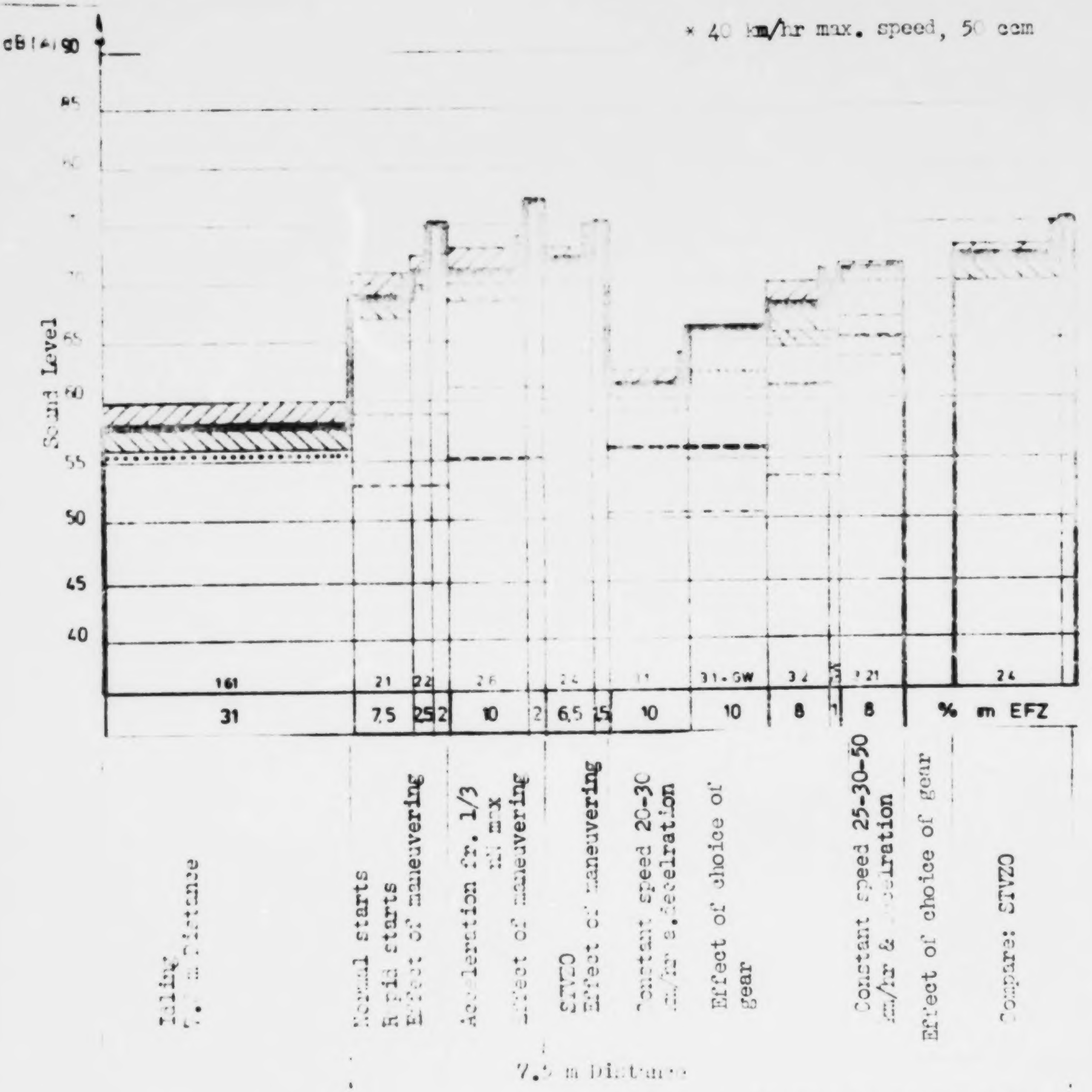


+) not shown

Fig. 20
Type of vehicle: Moped*

Noise Emission and Distribution in Urban Traffic from the European Driving Cycle for Exhaust Gas Emission (EFZ) Test Distance 7m and 7.5m

* 40 km/hr max. speed, 50 ccm



Upward range
Downward range
Influence due to maneuvering*)

Effect of road surface
- - - - Rolling Level
Limit of economic efficiency
——— Arithmetic mean

*) not [illegible]

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Fig. 21
Type of vehicle: light motorcycle*

Noise Emission and Distribution in Urban Traffic from the European Driving Cycle for Exhaust Gas Emission (EFZ) Test Distance 7m and 7.5m

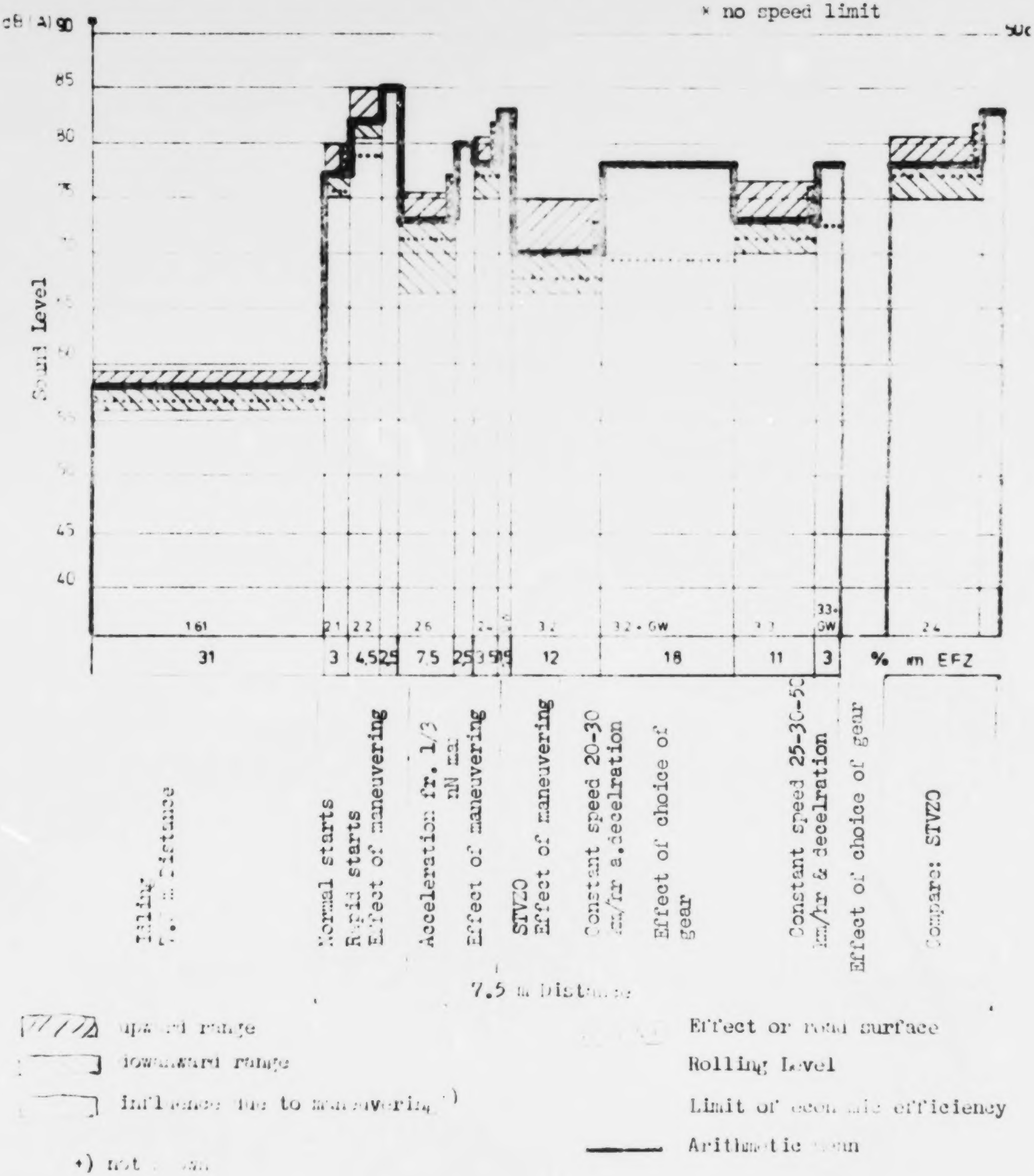
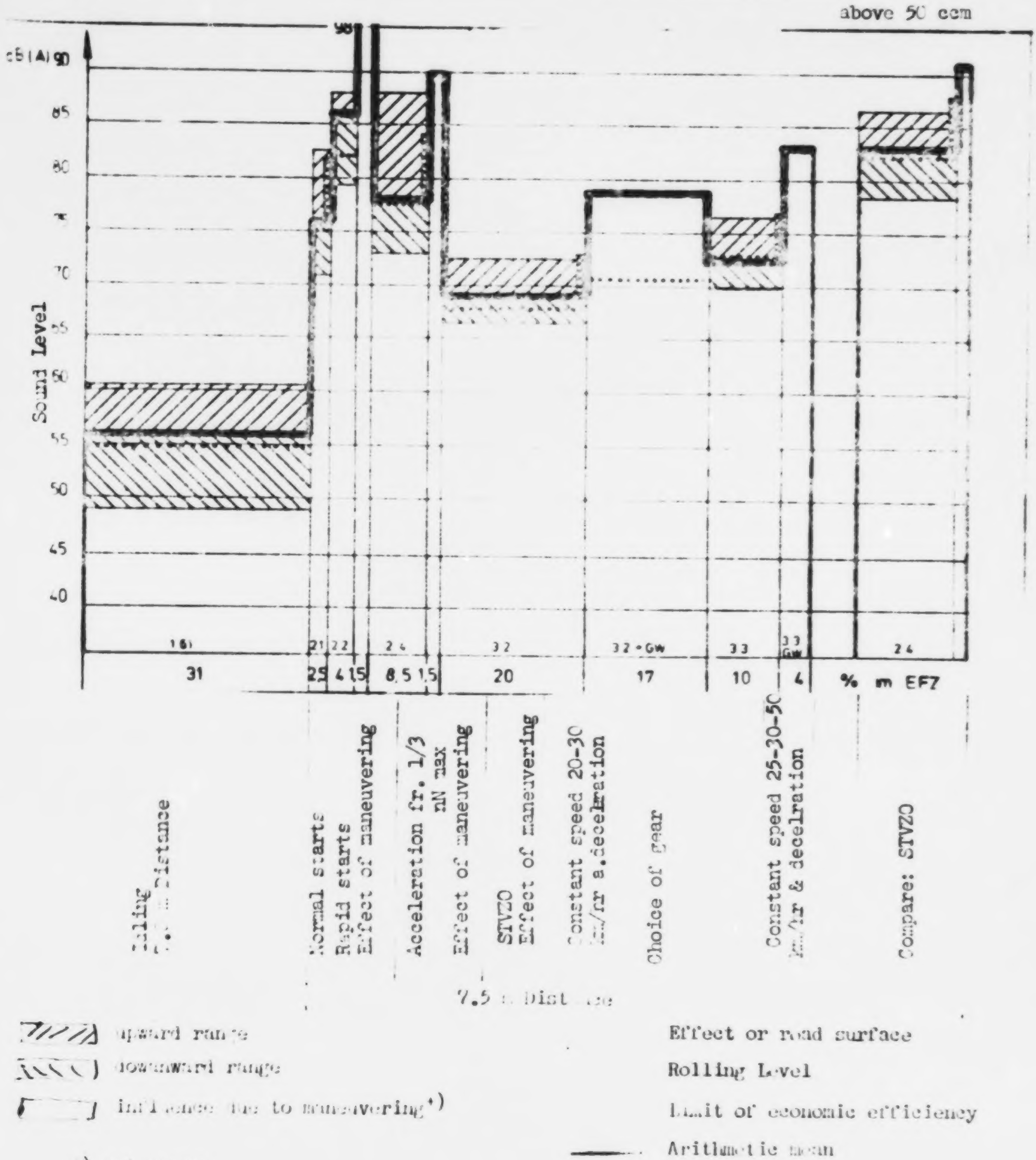


Fig. 22
Type of vehicle: Motorcycle

Noise Emission and Distribution in Urban Traffic from the European Driving Cycle for Exhaust Gas Emission (EFZ) Test Distance 7m and 7.5m



+) not shown

of 79 dB(A) and 84 dB(A) are prescribed, respectively. In fig. 13 noise generation and the rolling level is given for light motorcycles without speed limit. Fig. 14 gives the same data for motorcycles above 50 ccm.

2.2.6 Noise Distribution for the Various Types of Vehicles in Consideration of the EFZ

In section 1.3 the noise distribution, in consideration of the EFZ, was discussed. The results of this evaluation are given for the various types of vehicles in figures; fig. 15 gives the distribution for passenger cars, fig. 16 for light trucks below 3.5 t, fig. 17 for trucks above 3.5 t, fig. 18 for electric buses, fig. 19 for Mofas, fig. 20 for Mopeds, fig. 21 for light motorcycles and fig. 22 for motorcycles.

In these presentations the level height of starting and accelerating is clearly pointed out, although graphically the same, but temporally different processes are summarized in a %-value. The rolling levels and the economical limiting values in these diagrams permit a statement on the actual minimum level and show the physical limits of meaningful noise protection measures. Evaluation of the water-cooled passenger car with automatic gear shift, see fig. 6, that was made separately, demonstrates that this type of car nearly achieves the economic tolerance level.

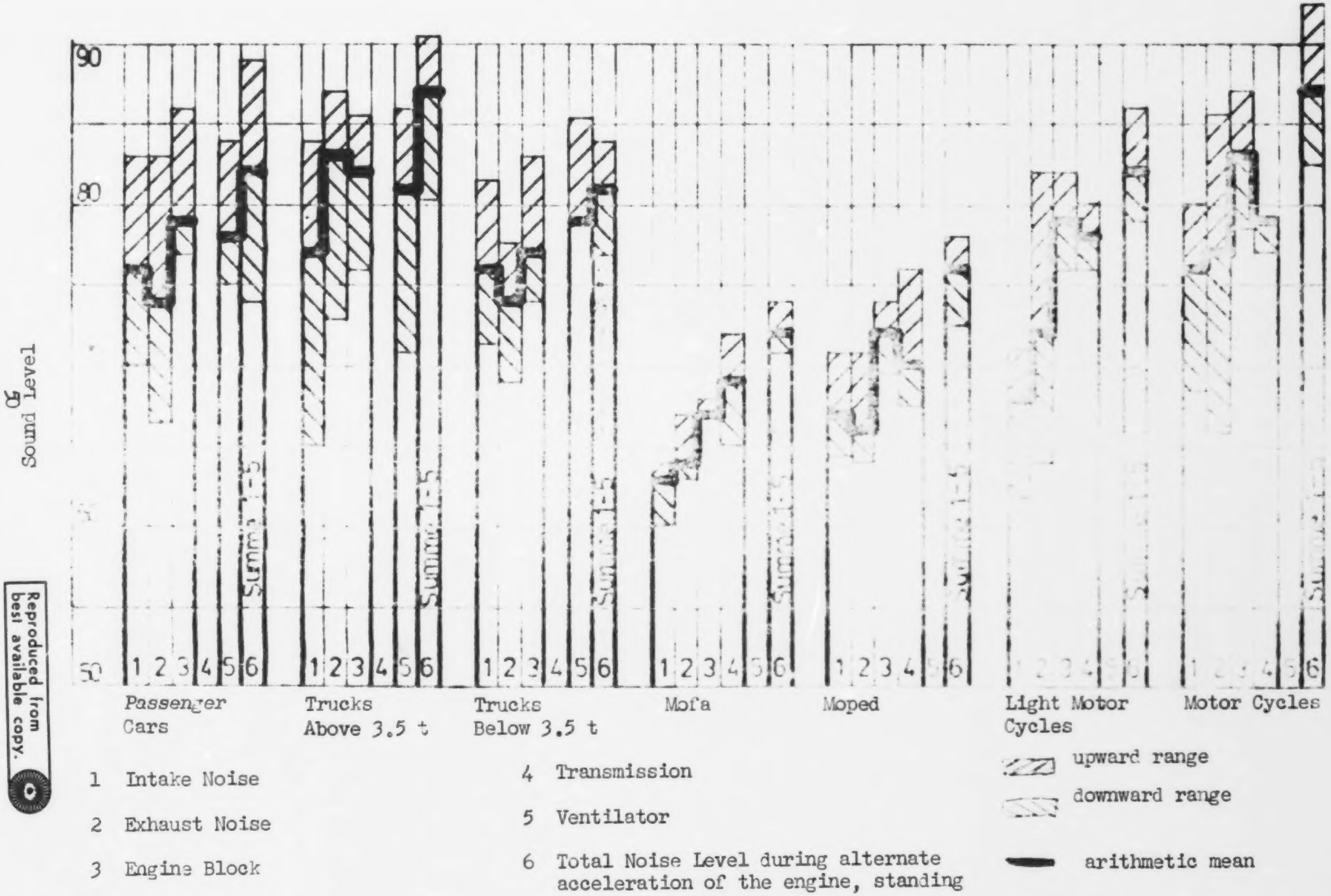
3. Summary of the Present State of Technic for the Individual Categories of Vehicles

3.1 List of Diagrams Showing Individual Average Distribution Levels

If one wishes to properly judge the state of technology in the wider sense of this survey, one must not limit one's self to a comparison of the measured inspection values, but one must try to determine to what extent partial levels contribute to the overall noise.

Fig. 23

Distribution of Partial Noise Levels During Standing at nNmax and Alternate Acceleration, Dist. 7.5 m



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Noise Levels for Various Types of Vehicles under Traffic Conditions Typical for Urban Areas.

Test Distance 7.5 m.

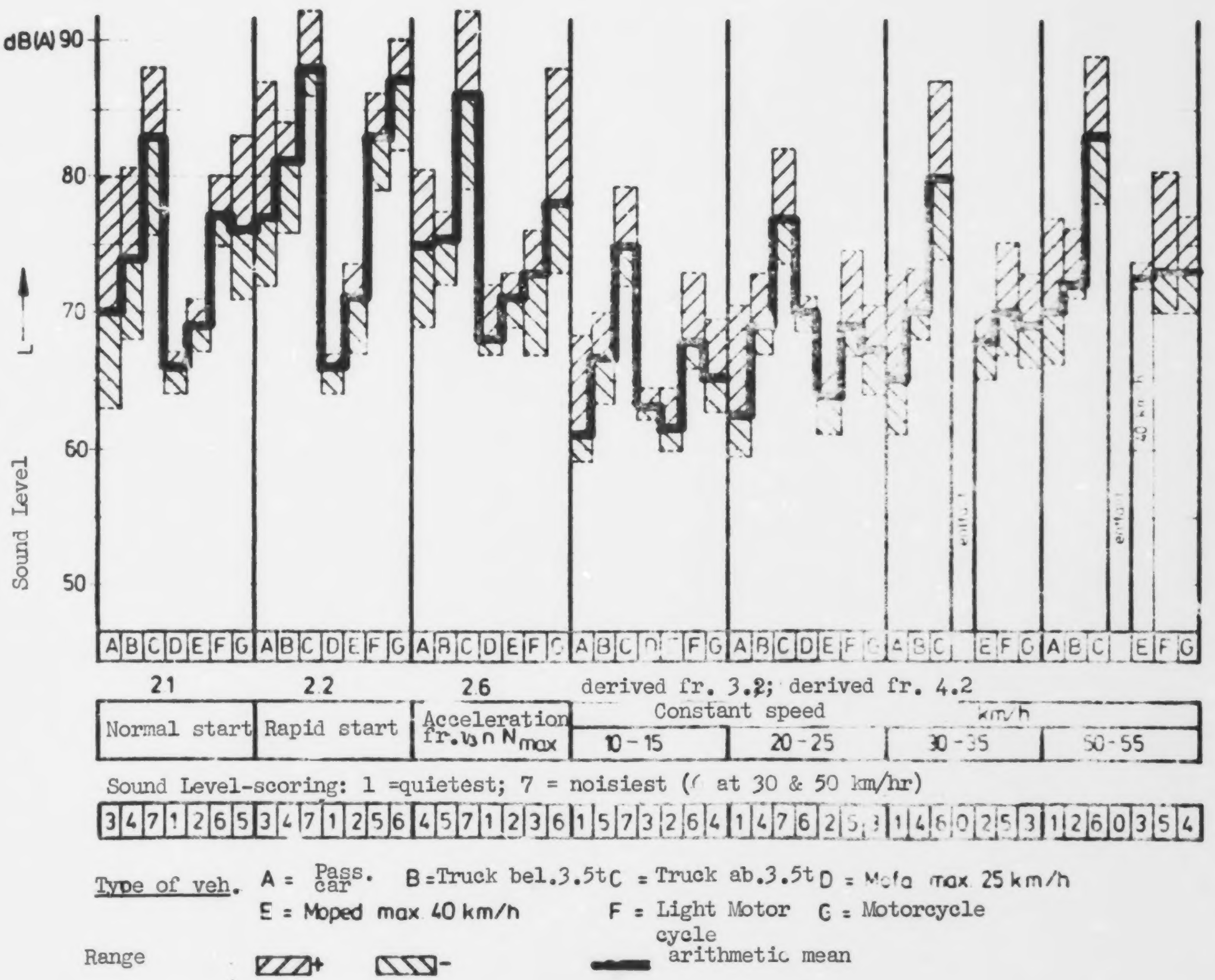


Fig. 24

For this purpose near-field measurements and experiments with supplemental dampening devices were included in the measurements in order to determine the effect of the exhaust noise under various operating conditions. Examination of individual types of vehicles gives a very varied picture. In addition to vehicles with excellent intake and exhaust systems there are individual types where in certain operating phases through improved intake- and exhaust dampening 5 - 6 dB(A) noise reduction could be achieved. These values do not apply to the top level noise, which is determined by the category, but to driving processes that are especially characteristic for city driving, such as starting and accelerating noises and gear shifting. (33, 34, 11, 12). It appears, therefore, indicated to pay more attention to these necessary supplementary devices and their tune-up in the combustion engine. The result of the measurements is given in fig. 23 for all passenger cars and trucks of all categories as well as for cycles.

Noise Distribution in Urban Areas

Fig. 24 gives important information. Emission values for the individual types of vehicles typical for urban traffic conditions are summarized into operational groups. Furthermore, absolute emission values at a distance of 7.5 m and the ordering of vehicles, are given. The following facts emerge clearly:

1. All starting and acceleration processes are quietest in Mofas and Mopeds, compared to passenger cars, light trucks, light motorcycles and heavy trucks.
2. At constant driving speed in the range of 55 km/hr the passenger car is the quietest vehicle, before Mofas and Mopeds, motorcycles and trucks.
3. Heavy trucks are loudest in all operating phases and generate levels

exceeding those of passenger cars by 10 - 15 dB(A).

3.2 Effects of Handling

3.2.1 State of Technology in Urban Traffic

The state of technology in urban traffic must not be equated with limiting values, as already pointed out in section 1.3. As a rule, the average level of passenger cars and light trucks lies 10 - 15 dB(A) lower, that of heavy trucks and cycles about 5 dB(A) below the level characteristic of the type.

If vehicles are driven in a racing manner (driving the motor to the maximum number of revolutions) the limiting values can also be reached or exceeded even in city driving. This is only possible with few vehicles (15%).

3.2.2 Closing of Doors

The importance of individual handling of vehicles by their owners is shown unequivocally by a comparison of rows 1.11 with 1.21 and 1.1 with 1.2 in figs. 2,7, 8 and 9 where for various types of cars effects up to 12 dB(A) can be demonstrated due to loud or quiet closing of doors.

3.2.3 Rapid Starts

Comparisons between rows 2.1 and 2.2 in figs. 2, 7, 8 and 9 show the acoustic consequences of too rapid starts. Depending on the type of car and motor output effects between 2 and up to 14 dB(A) can be demonstrated. Sudden noise increases are experienced as especially annoying by pedestrians and residents of neighboring buildings. The question arises whether the state of technology is not to be judged according to considerations of wider scope and in view of the present limiting values needs to be supplemented (see section 5.3).

The following noises due to handling deserve mention:

3.2.4 Squealing of Tires due to Starts at Full Motor Output

Depending on the size of the vehicles, the type of tires, the road surface and the way of operating the car, noise levels in excess of the limiting values are measured. 86 - 88 dB(A) are not infrequent and are experienced as annoying compared to the average noise level.

3.2.5 Squealing of Tires due to Excessive Speed in Curves

This type of noise, too, exceeds the limiting value and levels of 85 to 90 dB(A) can be measured. Many technical considerations enter into this, such as the state of the tires, the kinematics of the front axis, the weight of the car, the radius of the curve, etc., such that the speed limit for such noise generation is very flexible. Some times these noises are, for technical reasons, already generated at speeds from 30 km/hr. In most cases, however, (about 90%) they are due to a "racing" handling of the car and excessive speeds in curves.

3.2.6 Negligent Use of the Warning Signals

In Germany, but not in southern countries, this type of noise has lost in importance; this testifies that in the long term driver's education, prohibition of sounding the horn, etc. are not altogether useless. The noise level such signals generate is about 96 - 100 dB(A) and thereby exceed the limiting values by 14 - 18 dB(A) compared to permissible levels. Their use should be permitted only in the strictest emergencies. This applies also to ambulances and the sirenes of police cars and fire engines.

3.2.7 Squealing of Brakes and Wheel Blocking

The causes for squealing of brakes are mostly of a technical nature, but are sometimes due to driving behavior because a hesitant and long lasting braking leads to heating of the brakes and to the formation of "glass" on the surface of the brake shoes. This noise with a level of 85-92 dB(A) is today rarely observed with passenger cars, but still sometimes with trucks. Its pitch is annoying.

Strong braking with wheel blocking is to be avoided. Some drivers brake in this fashion although no real emergency exists. Levels up to 88 and 90 dB(A) can thus be generated.

Against such individual habits driver's education, but also legal ordinances can be helpful. (see section 5.2.2 and 5.3).

3.3 Criteria for Partial Noise Levels of Motor, Intake and Exhaust of Various Types of Vehicles

In agreement with other authors on the subject (4, 31, 32) the following must be pointed out:

3.3.1 The Motor Noise Level

With well developed intake and exhaust systems the loudest noise is always generated by the motor itself when idling at the maximum number of revolutions. When driving, it can be covered by the general driving noise (tires). Its characteristic is nearly independent of the driver. In fig. 25 average noise curves are given as a function of the number of motor revolutions for various types of motors and after elimination of intake and exhaust noises. The figure demonstrates the known fact that the noise curves of various motors are nearly linear with increasing number of revolutions and that higher noise can be expected from Diesel- and Otto motors with air cooling systems.

3.3.2 Intake and Exhaust

It is a different matter with intake and exhaust noises. They not only depend on the number of revolutions but in much higher degree on the extent of the load, whereby a further distinction is to be made between Otto- and Diesel motors. Otto motors are more dependent on the load than Diesel motors (31). The graphs in fig. 26 show a much flatter curve with a sharp increase in the low range of revolutions. As a consequence, when intake and exhaust installations are poorly tuned or poorly handled, the noise generated by the vehicles, especially at the start and when accelerated in low gear, is greatly increased, without necessarily exceeding the limiting value for its category.

Such vehicles, often referred to as "sports types", can generate excesses up to 10 dB(A) at the start and during acceleration without the possibility of legal action because this type of operation is not subject to inspection and the limiting value for the category is perhaps not exceeded. Yet in urban areas such vehicles are very prominently noted.

The low frequency of humming noises is propagated over long distances in narrow streets and the annoyance factor of vehicles handled in this fashion is three times that of ordinary cars.

In addition, such vehicles are often equipped with a modified engine. Instead of the usual 4-gear engine that is inspected for noise generation in the second gear, i.e. at 60 - 75% of the maximal number of revolutions, a 5-gear engine is used that is inspected in the third gear. Acceleration is this case at 50 km/hr is minimal and the number of revolutions at the type inspection is sometimes as low as 35 - 40% of the maximal permissible number of revolutions. Layouts 3 and 4 demonstrate the extent of these factors. The percentages of starting and motor revolutions for all types of vehicles,as they were determined in measurements, and for all operating conditions are there summarized. It is evident that the starting number of revolutions depending on motor output and gear mechanism lies between 35 and 75% of the maximum and the maximum revolutions between 45 and 110%.

Light motorcycles can have similar effects in city areas when they are driven at full motor speed which is the usual case in the interest of traffic flow. These are experienced as more annoying due to their higher frequencies. If certain manipulations of the intake and exhaust systems are added which occurs here more frequently than on other types of vehicles, these vehicles become determinant for the overall noise level, especially at night time. Also, the number of such vehicles in individual EG-countries varies greatly. In Germany the contribution by Mofas, Mopeds and light motorcycles is about 3%, the number of motorcycles is less than 2%.

Motorcycles, especially those with four-stroke cycles, have a less annoying frequency spectrum. If driven in a considerate manner they are not experienced as particularly annoying. It must be mentioned, however, that certain foreign vehicles are equipped with removable dampening devices that invite manipulations that lead to considerable excesses. With such vehicles the loudest noise levels of 97 - 98 dB(A) were measured, i.e. 13 - 14 dB(A) above the value for the category. The thundering noise of starting and accelerating such vehicles is in narrow streets experienced as unacceptable disturbance.

These large differences demonstrate clearly that present measurements for typing vehicles are at least questionable as the sole criterion in the

Fig. 25

Average Noise Level of a Built-in Car Engine in 7.0m Test Distance, Average of the 4 Test Directions.

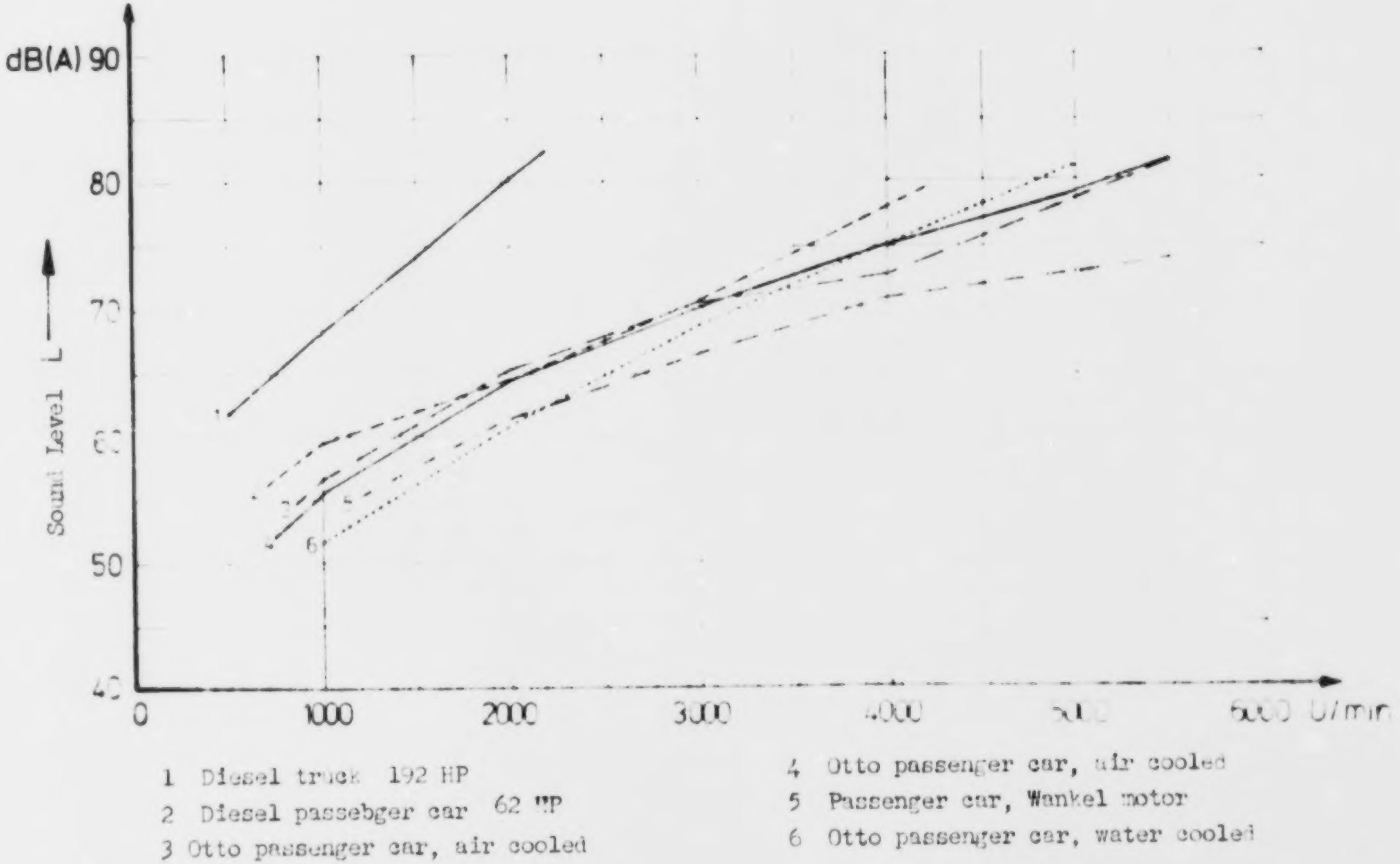
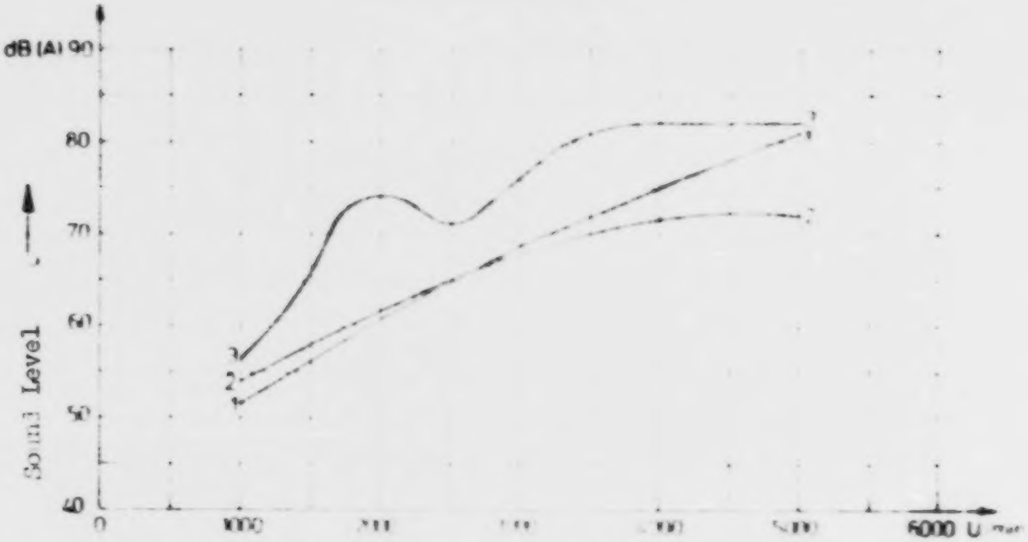


Fig. 26
Otto- or Diesel motors

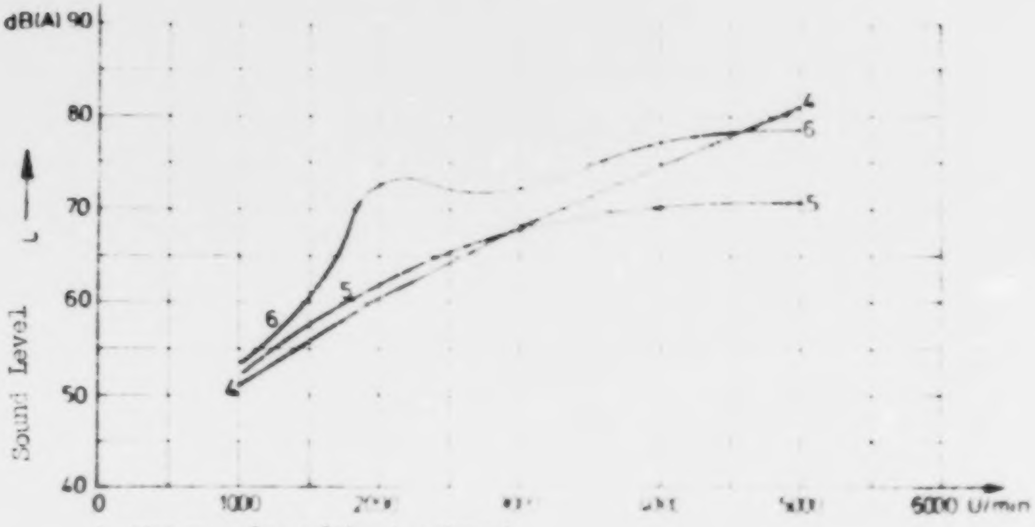
Intake-and Exhaust Noise Levels as a Function of the Motor rpm., 7.0m Dist.

Exhaust Noise Level



1 Noise Level for well developed exhaust-and intake systems
2 Exhaust - partial noise level, good
3 Exhaust - partial level, manipulated or poorly developed (ex.)

Intake Noise Level



4 Motor noise without exhaust
5 Intake - partial level, good
6 Intake - partial level manipulated (example)

determination of the noise level in urban areas and the question arises whether meaningful supplements to typing examinations are not in order for city traffic. It must also be pointed out that a required lowering of the limiting values at the categorizing inspection would change little in the state of affairs as discussed above. Even a drastic lowering of the values cannot influence the typical criteria of city driving (starting and accelerating) to any significant extent. Only an effective control of the parameters, acceleration and start, would have an effect on the noise level in urban areas with relatively small expenditures.

Suggestions are made in sections 5.3.2 and 5.3.3.

3.4 Considerations of the Rolling Noise Level, Road Conditions and Tires

Despite the relatively low driving speeds in city traffic the rolling noise level is of importance. The rolling noise level is not a fixed magnitude, but is dependent to a high degree on the type of vehicle, the weight, the type of tires and the road surface. During this investigation it became evident that not only the road surface but the whole road construction must play a role because for relatively similar weights and types of tires and similar surfaces very different rolling noises were sometimes measured. Apparently the quality of the road foundations (relatively hard and compact with crushed rock) or relatively soft (e.g. bituminous gravel on sand) play a role. Acceleration measurements on the road surface at the StVZO made by the team of Heinrich Gillet KG showed, that depending on the temperature of the road surface and the weather, acceleration can vary by a factor of 4. On icy roads even higher values were obtained. These few remarks show that the interplay between tires and road surface appear to have very complex acoustic effects and many questions demand clarification which, however, are beyond the scope of this study. The effective rolling noise level is also the key to the question whether expensive technical measures for the noise reduction can be meaningful. When the overall noise level approaches that of the rolling level by plus 3 dB(A) and, therefore, the noise generated by the engine is equal to the rolling noise it appears questionable to entertain expensive measures for noise reduction because the economics of such measures is simply not given and its practical usefulness is offset by the rolling noise.

For speeds exceeding 60-70 km/hr for passenger cars, 70 km/hr for light motorcycles, 100 km/hr for motorcycles and 50-60 km/hr for trucks the rolling level is normally decisive for the averall noise level. Since for trucks the load has a considerable influence on the noise of the tires (48) the limit can also be moved downward to 30 km/hr.

It can therefore be stated that for higher speeds, especially on highways, no noise reduction can be expected from technical measures, no matter how expensive, because the interplay of tires and road surface determines the noise level decisively.

Generation of rolling noise levels and the possibilities of their reduction was discussed extensively with experts of the tire indistry. Fig. 27 shows the variety of tire profiles in use today, that is added here with the kind permission of Dr. Zoeppritz. The diametrically opposed requirements facing the tire manufacturer can be partly seen from fig. 28, where requirements, possibilities of construction, advantages and disadvantages for some parameters are compared. (42).

Fig. 29 gives measurements of tire generated noises at a distance of 1.5 m. Upon conversion to 7.5 m distance good agreement between the measurements presented in this survey and previous publications (12) is obtained.

Prevailing tendencies in the development of tires that require greater safety on the road, also in rain, high steadiness in curves, a long lifetime and improved manouverability, hardly permit a reduction in rolling noises. The belt tire is coming into greater use for safety reasons. Due to insertion of steel cords into its rolling surface, which can be simple or consist of several layers, the tendency is toward a noise increase, see fig. 29. Lately there have been reports on a "compromise" tire (43).

Three main causes contribute to the generation of noise by tires:

1. The hollow body under air pressure behaves like a resonance box, that is set into vibration by the course of the profile on a road surface that is as flat as possible, with maxima and minima (profile noise - tire base noise - that varies greatly with the driving speed).

2. Push- and spring action that results from unevennesses in the road and the behavior of the suspension, push- and surface noises, that can cause increases of up to 8 dB(A) on a rough road surface or paved roads.

3. The load on the tires, especially for truck tires. For trucks the load on the tires can vary in a ratio of 1:3 (for passenger cars the ratio is 1:1.4). Depending on the type of profile this can cause up to 2-8 dB(A) noise level increases (48).

According to American investigations (48) various types of profiles of truck tires can, for loaded trucks in a range of 50 to 80 km/hr and on a rough surface, produce noise level differences of 17-20 dB(A) and on asphalt 10-13 dB(A). The tire profiles that were measured within the frame work of the EG-survey lie in the lower(quieter) third of possible profiles.

Fig. 27

Passenger Car- and Truck- Tires, Chart of Profiles

Tires for Passenger Cars

Winter (M & S)

Type of Construction
Diagonal Belt

Type of Construction
Diagonal Belt

Type of Construction
Diagonal Belt

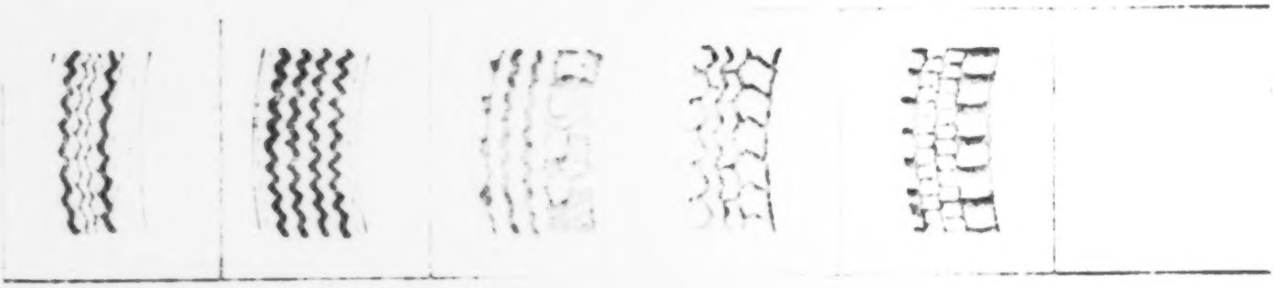
Tires for Trucks

S & G

M & S

Type of Construction
Diagonal Belt

Type of Construction
Diagonal Belt



From: Dr.-Ing. H. P. Zoeppritz
Phoenix - Gummiwerke AG, Hamburg

OVERVIEW

Requirements, Constructional Measures and Disadvantages of Tires for Motorized Vehicles

Requirements	Constructional Measures	Disadvantages
Good traction; Short stops on wet and slippery roads	Transverse grooves in profile Extensive and densely profiled Flat Surface Wide Surface	Noisy; Uneven wear Louder rolling noise Greater effort in parking
Low rolling noise a) in straight driving b) in curves	Profile: lengthwise grooves, No dense profiles, no transverse grooves, Basic support: Rayon Rolling surface: good dampening action	Reduced safety on slippery roads Higher rolling resistance
Safety in winter traction on snow traction on ice	Coarse winter profile Spikes	Increased wear and tear limited speed performance noisy limited utility on dry roads

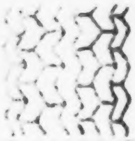
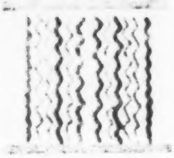
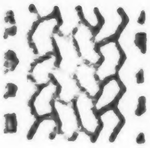
From: Dr.-Ing. H. R. Zoeppritz, Phoenix-Gummiwerke AG, Hamburg

Fig. 28

Fig. 29

Sound Level of Tires with Different Profiles

Values in parentheses are adjusted for a distance of 7.5 m: average correction factor 13.

		Fine grained Asphalt 60 km/hr		Coarse grained Asphalt 90 km/hr	
		3. Gear	Coasting	4. Gear	Coasting
	Block Profile	85 (72)	81 (68)	91 (78)	87 (74)
	Groove Profile	85 (72)	81 (68)	91 (78)	87 (74)
	M & S without Spikes	87 (74)	84 (71)	93 (80)	89 (76)
	M & S with Spikes	91 (78)	87 (74)	95 (88)	91 (78)

from Dr.-Ing. H.R. Zoeppritz, Phoenix-Gummiwerke AG, Hamburg

Special tires for cross-country driving and truck profiles with hollow spaces in the rolling surface can produce higher noise levels up to 10 dB(A), whereby, according to American measurements, (48) at a distance of 7.5 m rolling levels between 85 - 90 dB(A) at 50 km/hr and 90-98 dB(A) at 80 km/hr were measured.

Special tires with spikes for trucks increase the rolling level by 6-8 dB(A) at between 30-70 km/hr.

All tire profiles are quietest when they are new (full depth of the profile). When the depth of the profile is used up to about 50% a level increase of 1-4 dB(A) results.

Weather conditions can influence the rolling noise level considerably compared to a dry road surface. Fresh snow reduces the noise level by 5-15 dB(A). Humidity and strong rain increase the level, whereby, depending on the road surface, the type of tire and vehicle and depth of the water film on the road surface, values between 1-12 dB(A) have been measured (32).

3.5 Technical Monitoring and Indication of 3 Main Areas

The general technical monitoring of vehicles and inspections by the police discover amny shortcomings and certainly contribute significantly to the safety on our roads.

But local conditions do not, in most cases, permit rechecking of values appropriate for the categories concerning noise development (conditions of the place of measurement, environmental noise). Drivers of cars tuned up to racing performance need, therefore, not worry. Existing inspection regulations hardly permit a direct exmination at the bi-annual inspection. In order to permit this, present regulation would have to be replaced by other, supplemental regulations. For details on this point see section 5.3.4.

The present investigations confirm and renew the results by Reinhold published under the heading "Magnitudes to characterize the noise situation in streets" (33) that showed unequivocally that the annoyance factor in urban areas depends to a large extent on the difference in noise level above the basal level. Within the city limits vehicles of all types are experienced as disturbing if they cause high noise levels already at low speeds and small load increases cause rapid and steep changes in the noise level. This is often the case when a vehicle, because of insufficient motor output, is driven to the maximal number of revolutions in the first or second gear in order to achieve a desired acceleration. (For instance small cars, light motorcycles and motorcycles with insufficient tuned up exhaust systems). A similar behavior arises with vehicles of greater motor output when intake and exhaust systems are being tuned to "sound sporty", especially in the lower range of revolutions. For Diesel motors of trucks the reason is the effectively higher motor noise level and the high percentage of maximal revolutions at the start and during partial acceleration in city areas.

Summarizing briefly the above remarks it is to be stated that efforts in three main directions are required to improve the state of technology conerning the lowering of noise in urban areas:

1. Improved technical surveillance to determine:

1.1 Negligent modifications of vehicles that contribute to noise increase.

1.2 Normal wear and tear of the vehicle that contributes to noise increase.

1.3 Legislation to remedy 1.1 and 1.2. In table 8 present emission values are tabulated for passenger cars, light trucks, heavy trucks and electro-buses. Also given are values for various driving noises, rolling levels, effects of handling and manipulations, of the state of the road surface, as well as the percent contribution of each of these with their respective standard deviations.

Table 9 gives the same relationships for all types of cycles.

2. Unequivocal stipulation concerning individual handling by drivers and their responsibility for a quiet manner of driving (drivers' education) see also section 5.2.

3. Further technical measures and precise suggestions discussed in section 4.

4. Investigations of Measures to Reduce Noise on the Individual Vehicle

4.1 General

This is the most complex part of the survey and some preliminary remarks are necessary before presenting the individual technical measures that have been discussed with the associations of the automobile-and motorcycles industry. (40).

When the purpose of the survey was discussed, it had been pointed out that for each measure its effect as well as its cost is to be examined: for an objective appreciation economic evaluation factors are required that relate effect and expenditures. Section 5.1 and layout 5 contain suggestions.

The prices given are gross prices including the value-added tax. (Consumer prices) Basis: 1. 1. 1972.

Data on the acoustic effectiveness give the effect that the partial improvement has on the overall noise generation.

The value for the improvement of the partial noise level has to be much larger; e.g. if the overall noise level is to be reduced by 2 dB(A) the partial noise level has to be reduced by 6 dB(A).

State of legislation: 1. 1. 1972 and the regulations governing type examinations valid at that time. Future changes thereof could change the data about possible reductions in noise levels adversely.

4.2 Limitations of Effectiveness

A further difficulty arises from the fact that some of the suggested measures may be excellently suited, in terms of their technical efficacy, to reduce the noise of certain modes, such as idling or acceleration, but can be totally or partially offset by other partial noise levels, e.g. of the motor or the tires, whenever these partial levels dominate the overall noise emission.

4.3 Noise Level Distribution According to the EFZ

It is therefore not sufficient to compare only expenditures and efficacy, but at the same time the frequency of the respective level in the city must be determined at least approximately, in order to gain an additional dimension for a further economic evaluation, see also 2.2.6.

4.4 Degree and Timing of Realization

Of further considerable importance is the question whether suggested measures can be realized in the short term, or only upon reconstruction of the vehicle, or whether it must await a new generation of vehicles altogether. In view of these questions the suggestions concerning passenger cars, light and heavy trucks, were subdivided into three main groups, namely:

1. Measures that can be realized in a relatively short time and do not require changes in the overall concept of existing vehicles.
2. Measures requiring a longer time to develop.
3. Measures requiring a change of the overall concept of the vehicle.

For trucks below 3.5 t a fourth stage for accessory drives was envisioned. The measures in group 1) could be realized in 2-5 years, those in group 2) in 6-8 years, whereas those in groups 3) and 4) might need additional research before their possible realization.

For Mofas and Mopeds the measures were not subdivided in the same way, because the concept of these vehicles requires different considerations. But two stages were distinguished.

4.5 Cost Basis for Individual Vehicles

The costs for the individual vehicle can be determined accurately only for each individual case, the difficulty being that the state of technology as it applies to various types of vehicles, is very different. Comparing, for instance, vehicles No. 127 and 109 or 110, passenger cars of approximately the same weight and output, it is evident that for vehicle no. 127 the rolling level is determining in nearly all driving modes, i.e. that additional technical improvements would result in a maximum change of 1 - 2 dB(A), whereas for vehicles 109 and 110 considerable differences between the rolling and the driving levels exist. The passenger car 127 is in many operating modes quieter by 7-10 dB(A) compared to passenger cars 109 and 110. In view of such differences in noise levels it is practically impossible to indicate exact values that would apply to all vehicles. Additional costs differ from one type of vehicle to the next. This is further discussed in section 5.1.

It seems, therefore, advisable not to introduce the full value given for the individual vehicle into a cost estimate nor to multiply such a figure peremptorily by the number of existing vehicles, but to assume certain percentage only. Owing to further technical developments in the next few years many vehicles will be equipped with improvements that will approach a limiting noise value for the rolling level that is technically possible.

4.6 Effect of Competition

Considering the possible technical measures and requirements the question of competition also arises. All suggested measures are technically realizable. However, they will only partially be accepted, namely in those cases, where the valuation factor is economically advantageous or where other competitive considerations, such as an outstanding inside noise level, make them attractive.

In discussions with representatives of the automobile industry the point was repeatedly made that a competitive posture in the world market, compared to other producing countries, is of decisive importance. German cars are already now considered expensive in certain markets. The demands concerning quality and noise protection differ widely in importing countries. Some make very high demands of noise protection, other prefer vehicles with a "sporty" sound.

4.7 Influence of Consumer Classes

Last not least, the consumer classes play a further large role. Since for light motorcycles with a cubic capacity of 50 ccm a class 4 licence is required that can be obtained at the age of 16, the opinions and preferences of young consumers contribute to determine the product. Eight years ago a motorcycle of 50 ccm capacity developed 2.5 HP, but today 5.5HP are not considered sufficient; 6.5 HP or 130 HP output per liter are required, to technically "satisfy" the customer. This results in 9,000 to 10,000 revolutions. The mechanical noise generation of these motors is thus easily understandable. In the opinion of the manufacturers a modification of the pistonhead would not lead to worthwhile changes of this category of vehicles. In this case the licencing policies play the decisive role. A possible replacement of the 2-stroke motor prevalent among vehicles of this category by a 4-stroke motor would not be useful either because, for equal motor output and cubic capacity, the 4-stroke motor would make an even greater number of revolutions.

We now present the technically possible measures and wish to point out that the list only contains the most important possibilities and that in individual cases additional measures to reduce noise by secondary or active sound protection can be of importance. Tables 1[illegible] - 14 apply.

4.13 Additional Remarks

To simplify the evaluation individual measures were combined into groups. Table 15 summarizes the data for the categories of passenger cars, trucks below 3.5 t, trucks above 3.5 t and E-buses. Table 16 gives a short version for cycles. These representations are useful for statistical calculations. For economic estimates of the partial study 1.3 special evaluations for individual types of vehicles were carried out.

Concerning motorcycles, the manufacturers are not in a position to make valid estimates, especially for improvements of body noise and partial encasings, because the technical solution can not yet be determined. The author is of the opinion that the indicated values can serve as a useful basis for an estimate.

We cannot exclude the possibility that similar objections can be leveled against individual measures for other categories of vehicles (passenger cars and trucks). This is not surprising because of the non-uniform state of technology, different constructions and requirements, sizes of vehicles and the widespread uncertainty as to technical solutions. However, the indicated values should be considered useful bases for cost estimates. For individual types of vehicles application of certain measures can already be very useful. What they are has to be determined experimentally for each type. An acceptable solution can then be obtained with relatively little expenditure. For new constructions acoustically more advantageous values may be obtainable at equal or even lower costs.

5. Summary of Results and Measures

5.1 Critical Evaluation of Feasible Measures and their Economy

An overview of all suggested technical measures shows that certain solutions recur as the ones of special efficacy. Although the technical conditions vary greatly between types of vehicles, we preferred to discuss an individual measure for all vehicle types tested together in one section and to consider their economy at the same time.

The author proceeded with his own considerations of these questions from the schemes presented in layout 5, 3rd edition, that represent the economic factors W_{L1}-W_{L4}. The following data are being considered:

1. The cost A in DM.
2. The sales price Q in DM.
3. The reduction of the noise level in dB(A) in a given driving mode.

4. The valuation factor for a given operating mode B that evaluates the individual operating modes according to their degree of disturbance;
5. The sound factor P that comprises the different noise levels of various types of vehicles and operating modes and the perception exponent.
6. The distribution factor F_V in urban areas from the EFZ. From these the economic determinants W_{L1}-W_{L4} were calculated (Details per layout 5).

From the index W_{L3} a preliminary choice and a statement about the economic value ofa given expenditure can be made. Measures with a low ratio of DM factors/dB(A) level reduction (approx. 20 DM, -) have a good chance of being realized.

Intermediate ratios (approx. DM 20,- but DM 70,-/dB(A)) level reduction will require longer times to gain acceptance.

Ratios of 70, - to 100,- DM/dB(A) will probably be realized only in new constructions. At the present time, considerations that form the basis for the economic indices W_{L3} and W_{L4} are not yet ascertained by medical and economic investigations. Since we are concerned here with relative values that should guide the preliminary choice by the engineer, the author is of the opinion that practical and suitable applications can be derived without the afore-mentioned valuations.

When in doubt the recognized factors W_{L1} and W_{L2} can be used.

5.1.1 Reduction of Intake Noise

The state of development of the necessary dampening devices of intake noises, air filter, dry air filters, oilbath air filters and dampening filters, is so advanced that the level of intake noises is close to, or below, the mechanical motor noise over the whole range of revolutions. In the range of high numbers of revolutions the level is regularly below that of the motor noise level by 5 dB(A) and with outstanding intake devices even as much as by 10 dB(A). For all types of vehicles to place an intake noise filter of sufficient size presents difficulties, which led for motor cycles to the use of the frame of the vehicles or special, additional spaces that are built into the frame.

The limited space under the hood of passenger cars leads to difficulties and considerable expenditures in some cases. The state of development for cycles and passenger cars is highest for intake filters, but not as advanced for trucks because of the higher motor noise levels, i.e. they are not built in as standard equipment. The intake noise for these vehicles remains definitely below the motor noise at high revolutions, but exceed that of passenger cars by an average of 3-5 dB(A). Spacial conditions are not advantageous for the installation of large filters but the problem can be solved by constructing the motor space correspondingly. For buses intake noise dampening devices are today already standard equipment. They bring intake noises to the level of passenger car values. Manipulation of intake noise dampeners are rare for passenger cars and trucks, except where cars are tuned "sportily" or standard air filters are replaced by rally - and racing air filters, but for motor cycles this is being done quite frequently. The connection between intake noise dampeners and the carburetor should be improved. Parts of man-made materials are often used here that dampen insufficiently in the critical range and can easily be manipulated or dismanteled. This part of the vehicles could, at minimal cost, be so modified as to still allow for manipulations by the owner but to reduce this by 90%.

Estimates according to the scheme of economic feasibility show that improvements of intake noise levels have advatageous DM-ration and a high degree of feasibility.

Fig. 30 shows the picture of a dampening filter and a diagram of the acoustic efficacy of this part. The high trapping action of modern filters (micronic filters) considerably lengthens the life of the motor. (21)

5.1.2 Exhaust Noise Dampening

In section 3.3 we discussed extensively the characteristics of exhaust noises. Since the length of the system is important for overall dampening different characteristics are found for motor cycles, vehicles with rear-motors, passenger cars with front-motors and trucks. The state of technology varies more here than for intake noise dampeners. Temperature effects, corrosion and increased dynamic requirements, together with resonances for long transmissions, make installations for exhaust dampening difficult. Systems with good dampening produce at low revolutions the same noise level as the motor. At high revolutions they remain below the motor noise by 3-8 dB(A). They are standard equipment today. Similar installations exist for trucks and well developed motor cycle exhaust systems.

But there still exist exhaust systems which, at low revolutions or even during idling, clearly emerge above the overall noise level and stand out partly because of body resonances. They exceed the motor noise level at low revolutions by 8-10 dB(A) and reach, or remain slightly below the motor noise level at high revolutions. Such poor installations often exhibit an even greater annoyance in the range of partial accelerations. In addition to German products, products of some foreign manufacturers are conspicuous in this regard. A professional examination of such cases always leads to the conclusions that for a specified cost exhaust systems could be developed that would give optimal effects. A small percentage of indicated costs would already bring noticeable improvement.

For motor cycles, especially Mofas, Mopeds and light motor cycles, exhaust systems exhibit predominantly a very good dampening with low absolute noise levels, but these can easily be manipulated because built-ins are necessarily removable, and owners often do manipulate their vehicles in this way.

The reflected body noises of the dampeners is covered up for motor cycles due to the higher mechanical motor- and transmission noise level so that its influence on the overall noise generation cannot be actually measured, but it contributes, together with reflections from other parts of the vehicle, to the subjective impression. Due to the necessarily rigid construction of the block body noises radiate throughout all parts. At the indicated cost improvement of body sound reflection and impediments to the removal of dampeners, which is possible through appropriate construction, an overall improvement could be obtained here. The volume of some dampeners would have to be increased by 50-100% which is possible through appropriate construction and without injury to style.

Removable installations for 4-stroke motors which exist for dampeners of foreign origin should be forbidden since they are technically not required and only invite manipulations. Fig. 26 gives the effective exhaust noise levels at the present state of technology.

It is evident that the spread is great. Since exhaust installations are not only manufactured by production line manufacturers but also by manufacturers of spare parts it is possible that parts of different quality are sold. The sale of such products cannot be forbidden in a free market economy but appropriate legal regulation should assure that such products equal the technical compromise that line products already represent.

The inspection procedure applied in Germany is objective and ensures to a high degree that dampeners installed subsequent to production are of the same quality as the line product in regard to noise development measured in dB(A). It requires supplementation of the following points:

Standardization of the minimal requirements of:

Lifetime

Quality of materials

Strength of materials.

N.B.: The manufacturers develop their products in hard continuous testing in order to determine the minimal requirement for quality and strength of materials used.

The type examination should require, in a legally binding fashion, the same durability, quality and strength of materials for products installed subsequent to production. If other construction principles are used their durability should be ascertained by dynamic vibration tests (test of elasticity under specified changes in the load and usage).

The intent is to make test conditions the subject of a national DIN-standard. In European foreign countries and oversees re-eaxaminations are not practised at all or procedures are used that are not technically suited to the specified purpose. Commissioned by the BMV, the PTB in Braunschweig has conducted surveys of the possible test procedures and have shown clearly that only tests of the vehicles themselves can give results that approach actual conditions. Unfortunately a worsening is to be expected in the future if the international ECE-regulation, that presently exists only as a draft, would be ratified. In it an examination for exchangeable noise dampeners is provided that would result in a clear lowering of present requirements. The question of durability is not being considered at all.

In addition to the noise dampening the difficult problem of corrosive wear of noise dampeners must be considered. This entails that exhaust dampeners change during continuous operation more than intake dampeners. If the installation is properly developed there is no risk of a considerable increase in noise generation. Continuous testing shows that deposits after long times of operation diminish, rather than increase, the exhaust noise level by 1-2 dB(A). However, this is true only for about 30-40% of all installations. For other systems changes inside the dampeners or holes in the outside casing or other causes bring about a break in the system that can result in increased noise levels. Such changes do not always lead to a total loss of the installation and a driver could drive such a vehicle for weeks before becoming aware of the damage. During this time the noise is, however, already increased. Measures to alleviate this condition are discussed in section 5.3.5. Constructional modifications and tuning devices must find here their deserved consideration that are being offered at high prices while their only effect consists of increasing the gasoline consumption and sometimes also a little the motor output with a simultaneous increase of the noise made by the exhaust. Such installations should be made subject to much more severe testing than has been done up to now.

In a summary evaluation of the problem of exhaust noise it is to be stated that the factor of manipulation is here higher than in the case of

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Table 8

Summary of the Results of the Survey "Costs for Modifications of Vehicles to Reduce Noise Emission". Short Representation of Present Emission Values for Essential Operating Conditions in City Traffic. Compare Driving Noise, Rolling Noise, Quantitative Data on Effects of Handling, Manipulations, Road Conditions and Percent Distributions. All Acoustical Values Are Given as Arithmetic Averages in dB(A). ± Values Give Standard Deviations.

a	b c	d	[illegible]				j Beschleunigung						k [illegible]rungen [illegible] konstante Geschwindigkeiten								
							1,5 m ([illegible]max)			[illegible]			50 km/h			[illegible] km/h			70 km/h		
				Pegelerhöhg.				Pegelerh.			Pegeler.			Pegeler.			Pegeler.			Pegelerh.	
Alle Werte in dB(A)	[illegible]	[illegible]	e Stand der Technik	f Einfluß durch Hand-habung	g Einfluß durch Manipulation	h Einfluß durch Fahrbahn und Randbebauung	e Stand der Technik	k Einfluß durch Manipulation	h Einfluß durch Fahrbahn und Randbebauung	e Stand der Technik	g Einfluß durch Manipulation	h Einfluß durch Fahrbahn und Randbebauung	e Stand der Technik	l Einfluß durch Handhabung der Handhabung	h Einfluß durch Fahrbahn und Randbebauung	e Stand der Technik	l Einfluß durch Handhabung der Handhabung	h Einfluß durch Fahrbahn und Randbebauung	e Stand der Technik	l Einfluß durch Handhabung der Handhabung	h Einfluß durch Fahrbahn und Randbebauung
m [illegible]	n Fahr-geräusch	[illegible]	[illegible]	[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	o Roll-geräusch		≈[illegible]-59	ab 5 km/h			≈[illegible]			[illegible]			[illegible] -2			[illegible] -2,[illegible]			[illegible]		
	p Diff. dB(A) ΔF-R		14-11				10-12			[illegible]			5						2		
	q % Anteil im Stadt-verkehr		7				[illegible]			[illegible]			31			14			0		
	r % Vertei-lung der Teilpegel		45	54	1	40	99	1	35	99	[illegible]	30	[illegible]	35	30	70	30	25	80	20	25
s [illegible]	n Fahr-geräusch (1) (2)	[illegible]	[illegible]	+5 [illegible]		4-7	[illegible]		4-7	[illegible]	[illegible]	4-7	70±2	4	4-5	$[illegible]^{+2}_{-1,5}$		4-5	$76^{+3}_{-1,5}$		3-4
	o Roll-geräusch		≈53-64	ab 5 km/h			≈60-66			≈65-65			$64^{+2}_{-2,5}$			69^{+2}_{-3}			$74^{+1,5}_{-2}$		
	p Diff. dB(A) ΔF-R		15-10				15-9			16-13			6			3			2		
	q % Anteil im Stadt-verkehr	55	12				12			0			33			12			0		
	r % Vertei-lung der Teilpegel		60	60		40	100		35	100		30	50	50	30	80	20	25	100		20
t Lkw > [illegible]	h Fahr-geräusch (1) (2)	66^{+2} [illegible] $61^{+6,5}$ [illegible]	$8[illegible]^{+5}_{-7,5}$	6^{+7}_{-4}		4-7	$86^{+5,5}_{-11,5}$		4-7	87^{+4}_{-3}		4-7	$80^{+6,5}_{-6}$	6		$84^{+5}_{-5,5}$		4-5	$86^{+6}_{-3,5}$		3-5
	o Roll-geräusch		6[illegible]-68	ab 5 km/h			≈64-70			≈69-74			67^{+8}_{-5}			$74^{+7}_{-4,5}$			$79^{+6,5}_{-4}$		
	p % Anteil im Stadt-verkehr	31	14				14			[illegible]			[illegible]5			8			0		
	q % Vertei-lung der Teilpegel		60	40		40	100		35	100		30	65	35	30	90	10	25	100		15
	p Diff. dB(A) ΔF-R		21-15				22-15			18-13			13			10			7		
u Elekt. Busse Nr. [illegible]	h Fahr-geräusch (1) (2)	$59^{+0,5}_{-1}$ $59^{+0,5}_{-1}$	$73^{+1,5}_{-1}$			4-5	$7[illegible]^{+2,5}_{-1,5}$		2-3	$76^{+1,5}_{-2}$		4-5	$68^{+1,5}_{-2}$	5	4-5	74^{+3}_{-2}		4-6	60 km/h $78^{+1,5}_{-2}$		3-5
	o Roll-geräusch		≈62-65	ab 5 km/h			≈66-68			74 Wert f. LKW 3,5 [illegible] 50 km/h			$66^{+1,5}_{-1}$			73^{+2}_{-1}			$76^{+0,5}_{-0}$		
	p Diff. dB(A) ΔF-R		11-8				6-4			2			2			1			2		
	q % Anteil im Stadt-verkehr		no data on electric vehicles																		
	r % Vertei-lung der Teilpegel																				

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Table 9

Summary of the Results of the Survey "Costs for Modifications of Vehicles to Reduce Noise Emission". Short Representation of Present Emission Values for Essential Operating Conditions in City Traffic. Compare Driving Noise, Rolling Noise, Quantitative Data on Effects of Hnadling, Manipulations, Road Conditions and Percent Distributions. All Acoustical Values Are Given as Arithmetic Averages in dB(A). ± Values Give Standard Deviations.

a b . d					i	j		i			i	k		i			i			i
		e	f	g	h	e	f	h	e	g	h	e	l	h	e	l	h	e	l	h
	c	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
v	n	[illegible]	[illegible]			[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	o	[illegible]				[illegible]			[illegible]			[illegible]			[illegible]			[illegible]		
	p	[illegible]				[illegible]			[illegible]			[illegible]			[illegible]			[illegible]		
	q	7				[illegible]			[illegible]			12			[illegible]					
	r	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	100		25			
w	n	[illegible]	[illegible]		[illegible]	[illegible]			[illegible]		[illegible]	[illegible]	20 km/h [illegible]	[illegible]	[illegible]	30 km/h 7	[illegible]	$71^{+[illegible]}_{-[illegible]}$	50 km/h 7	
	o	[illegible] ab 5 km/h				[illegible]			[illegible]			[illegible]			[illegible]			$65^{+[illegible]}_{-1,[illegible]}$		
	p	[illegible]				[illegible]			[illegible]			5			9			6		
	q	[illegible]				[illegible]			[illegible]			[illegible]			[illegible]			[illegible]		
	r	[illegible]	[illegible]	10	40	35	[illegible]	40	[illegible]	10	30	[illegible]	50	20	90	10	25	100		25
x	n	[illegible]	$^{+1,5}_{-1,5}$	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]			[illegible]	20 km/h 8	[illegible]	$[illegible]^{+3,5}_{-3}$	20 km/h 5	[illegible]-3	$78^{+1,5}_{-3}$	70 km/h 2-3	
	o	[illegible] ab 5 km/h				[illegible]			[illegible]			[illegible]			$[illegible]^{+3,5}$			$67^{+2,7}_{-3}$		
	p	[illegible]				[illegible]			[illegible]			[illegible]			9			11		
	q	10				[illegible]			[illegible]			[illegible]			14			[illegible]		
	r	30	5	25	40	75	[illegible]	30	75	5	30	40	60	20	80	20	25	100		20
y	n	$70^{+6,5}_{-5}$	$70^{+2}_{-4,5}$	12	3-6	78^{+10}_{-5}	12	3-6	$[illegible]^{+3,5}_{-4,5}$	8	4-5	$69^{+3,5}_{-[illegible]}$	10	3-4	73^{+4}_{-3}	10	3-4	76^{+4}_{-3}	[illegible]	3-4
	o	[illegible] ab 5 km/h				60-64			[illegible]			$[illegible]^{+4,5}_{-4,5}$			$62^{+3}_{-3,5}$			$67^{+2,5}_{-5}$		
	r	15-16				18-14			13-16			11			11			9		
		[illegible]				[illegible]			[illegible]			[illegible]			16			[illegible]		
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30	25	85	15	20

Key for tables 8 and 9

a) Category of Vehicle

b) Value (1) = 7 m sideways; value (2)= 7 m to the rear

c) All values in dB(A)

d) Idling of the motor during standing and coasting

e) State of the art

f) Effect of Handling

g) Effect of manipulation

h) Effect of the Road and bordering buildings

i) Noise increase

j) Acceleration

k) Deceleration and constant speeds

l) Effect of handling and choice of gears

m) Passenger Cars No. 100-150

n) Driving Noise F

o) Coasting noise R

p) Difference netween F and R in dB(A)

q) Percent share in city traffic

r) Percent distribution of partial noise levels

s) Trucks below 3.5 t no. 200-204

t) Trucks above 3.5 t no. 300-319

u) Electric buses no. 800-801

1) In this row the percentage share of partial noise levels according to EFZ is represented.

2) In this row is represented at what percentage the partial levels "state of the art, different handling, and manipulations", that were carefully evaluated, are to be assessed. The influences due to road surface and bordering buildings have to be evaluated independently.

v) Mofas no.400-402

w) Mopeds no. 500-503

X) Light Motorcycles no. 600-603

y) Motorcycles no. 700- 708

4.8 Possible Technical Measures to Reduce Noise Emission from Passenger Cars and Stationwagons and Their Influence on Various Operating Modes and Costs (Prices at 1.1.1972)

Type of Measure	Grade	Expenditures DM	Idling	Starting noise dB(A)	Accel., 2. gear 1/3 nNmax dB(A)	Driving noise StVZO 3/4 nNmax dB(A)	Driving at const. speed 30km/hr dB(A)	Driving at const. speed 50km/hr dB(A)	Driving at const. speed 70km/hr dB(A)	Remarks
			31	7	1[illegible]	[illegible]	38	14	[illegible]	% share in city traffic
Group 1 Measures without essential changes in the overall concept										
Improved intake noise dampeners Lmax. 70 dB(A) at 7.5 m distance in all operating modes		[illegible] [illegible]	-[illegible]							
Improved exhaust gas noise dampeners Lmax. 70 dB(A) in all rotational-and load ranges at 7.5 m distance	I	20,-	[illegible]	[illegible]						
Ventilator or Visco-ventilator that can be disengaged	I	60,- [illegible] [illegible]								
Sound proofing of the motor casing with absorption and supplemental rubber seals at the seams.		[illegible] [illegible]								
Functional, sound proof multi-sectional casing of the motor space at the bottom		[illegible] [illegible]								

Table 1[illegible]/1

Table 10/2

-.8 Possible Technical Measures to Reduce Noise Emission from Passenger Cars [illegible] and Their Influence on Various Operating Modes and Cos[illegible] ([illegible] at 1.1.1972)

			31	7	1		39			City Traffic	
Type of Measure			Acoustic efficiency on various operating modes								Remarks
							Driving at const. speed				
	Grade	Expenditure DM	Idling	Starting noise dB(A)	Accel. 2.? m/s² 1/3 nmax dB(A)	Driving noise StVZO 3/4 nmax dB(A)	30 km/hr dB(A)	50 km/hr dB(A)	70 km/hr dB(A)		
Use of automatic transmission to reduce noise at the start and during acceleration. Limit the effects of individual handling of the car.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
Group 2 Measures requiring time for development											
Sound proofing improvements of auxiliary units, e.g. transformer, injection pumps, drives, etc.	II	[illegible]0,- 120,-	0	0 - 1	[illegible]	[illegible]					
Improvements of the engine. Reduction of surface reflection at some critical points. Installation of sound proofing devices on the motor block cylinder head or other reflecting parts.	III	210,- 4[illegible]0,-	0	[illegible] - 4	[illegible]	[illegible]					

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4.8 Possible Technical Measures to Reduce Noise Emission from Passenger Cars and Stationwagons and Their Influence on Various Operating Modes and Cost. (Prices at 1.1.1972)

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Table [illegible]/3

Type of Measure	Grade	Expenditures DM	Idling	Starting noise dB(A)	Acc. 1.,2.gear 1/3 nNmax dB(A)	Driving noise StVZO 3/4 nNmax dB(A)	Driving at const. speed 30km/hr dB(A)	50km/hr dB(A)	70km/hr dB(A)	Remarks
			31	7	1	[illegible]	3[illegible]	14	[illegible]	% share in city traffic
Group 3 Measures requiring greater technological effort and time for development										
Sound proofing cool air circulation at the intake.	III	250,- - 450,-	0	[illegible] - 2						
Sound proofing cool air circulation at the exit of the motor.	II	[illegible],- - 200,-	0 - 1			1				
Enlarged cooling installation without motor-driven ventilator, but with controllable electric ventilator	III	150,- - 200,-	0 - 2	1 - 2	[illegible]	[illegible]				
Encased, sound proofed motor space with well functioning motor cooling. May need extensive changes of the driver's cab. Summary of grades I-III see Table 15	II	800,- - 1.600,-	2 - 4	4 - 6	4 - [illegible]					

4.9 Possible Technical Measures to Reduce Noise Emission from Trucks and Buses below 3.5 t and Their Influence on Various Operating Modes and Costs (Prices [illegible] 1972)

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Type of Measure	Grade	Expenditures DM	Idling	Starting noise dB(A)	Accel., 2. gear 1/3 nMmax dB(A)	Driving noise StVZO 3/4 nMmax dB(A)	Driving at const. speed 30 km/hr dB(A)	50 km/hr dB(A)	70 km/hr dB(A)	Remarks
			31	12	6	6	33	12		[illegible]
Group 1 Measures without essential change in the concept of the vehicle										
Improved and enlarged intake dampening system L_{max} less than 70 dB(A) at 7.5 m distance in all operating modes.	I	35,- 65,-	0	0 - [illegible]	0 - [illegible]	[illegible]	[illegible]	[illegible]	0	
Improved and enlarged exhaust gas dampening system, L_{max} less than 72 dB(A) in all rotational- and load ranges at 7.5 m distance.	I	45,- 85,-	0	0 - [illegible]	0 - 3	[illegible]	0 - 1	0 - 1	0 - 1	
Ventilator that can be disengaged (Visco)	I	130,- 230,-	0	0 - 2	0 - 1	0 -	0 - 1	0 - 2	0 - 2	
Sound proofing of the front and upper motor cover with absorption and supplemental rubber seals at the seams.	I	250,- 380,-	1	0 - 2	0 - 1	[illegible]	0 - 1	0 - 1	0 - 1	
Use of automatic transmission (Wandler)	II		0	4 - 5	2 -					

Table 11/1

4.9 Possible Technical Measures to Reduce Noise Emission from Trucks and Buses below 3.5 t and Their [illegible] Various [illegible] Mode and [illegible] ([illegible])

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Table 11/2

			31	12	6	6	33	12		[illegible] traffic
Type of Measure			Acoustic efficiency on various operating modes							Remarks
							Driving at const. speed			
	Group	Expenditures DM	Idling	Starting noise dB(A)	Accel. 1., 2. gear 1/3 nmax dB(A)	Driving noise [illegible] 3/4 [illegible] dB(A)	3[illegible] km/hr dB(A)	5[illegible] km/hr dB(A)	7[illegible] km/hr dB(A)	
Sound proofing improvements of auxiliary units, e.g. generator, injection pumps, drives, etc.	II	110,- 200,-	1	1 - 2	1	1 - [illegible]	[illegible]	0	[illegible]	
Group 2 Measures requiring time for development										
Functional, sound proofing, multisectional casing of the motor space at the bottom and possibly other sides.	III	280,- 120,-	1	0 - 2	0 - 1	1 - 2	[illegible]	[illegible]	[illegible]	
Group 3 Measures requiring greater technological effort										
Improvements of the engine. Reduction of surface reflection at some critical points. Installation of sound proofing devices with absorption on the engine block, cylinder head, or other reflecting parts.	III	490,- 1.100,-	3	3 - 5	4	1 - [illegible]	[illegible]	[illegible]	2 - [illegible]	

-.9 Possible Technical Measures to Reduce Noise Emission from Trucks and Buses below 3.5 t and Their Influence on Various [illegible] (Prices at 1.1.1972)

Type of Measure	Grade	Expenditures DM	Idling	Starting noise dB(A)	Accel., 2. gear 1/3 nMmax dB(A)	Driving noise StVZO 3/4 nMmax dB(A)	30 km/hr dB(A)	50 km/hr dB(A)	70 km/hr dB(A)	Remarks
			31	12	6	6	33	12		[illegible]
			Acoustic efficiency in various operating modes				Driving at const. speed			
ound proof cool air circulaton at the intake.	III	420,- – [illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	
ound proof coold air circulaton at the exit side of the otor.	II	[illegible] – [illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	
nlarged cooling system without otor-driven ventilator, but ith electric ventilator that an be disengaged.	III	[illegible] – 400,-	[illegible]	[illegible]	[illegible]				[illegible]	
ncased, soun proof motor space ith well functioning engine ooling. May require more extensive constructional changes of he driver's cab.	III	[illegible] – [illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	
ummary of grades I-III in able 15										

Table 11/3

Table 12/1

4.10 Possible Technical Measures to Reduce Noise Emission from Trucks and Buses above 3.5 t and Their Influence on Various Operating Modes and Costs (Prices at 1.1.1972)

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Type of Measure	Grade	Expenditure DM	Acoustic efficiency on various operating modes				Driving at const. speed			Remarks
			31	14	8	6	33	8		[illegible] city traffic
			Idling	Starting noise dB(A)	Accel., 2.gear 1/3 nNmax dB(A)	Driving noise StVZO 3/4 nNmax dB(A)	30km/hr dB(A)	50km/hr dB(A)	70km/hr dB(A)	
Group 1 Measures: Improved and enlarged intake dampening system L_{max} less than 75 dB(A) in all operating modes at a distance of 7.5 m	I	60.- 130.-	1	0 - 3	0 - 3	0 - 2	[illegible]	0 - 1	0 - 1	
Alternative values for V-motors		120. 160.-								
Improved and enlarged exhaust gas dampeners L_{max} less than 78 dB(A) in all rotational- and load ranges at 7.5 m distance.	I	60.- 120.-	1	0 - 2	0 - 5	0 - 2	[illegible]	0 - 1	0 - 1	
Alternative values for V-motors	I	140. 180.-								
VEntilator that can be disengaged (Visco)	I	180.-	1	0 - 1	0 - 1	0 - 1		0 - 1	0 - 1	
Sound proofing of the front- and upper motor cover with absorption and supplemental seals at the seams.	I	220.- 450.-	1	0 - 1	0 - 1	0 - 2		[illegible]	0 - 1	

Table 12/2

4.10 Possible Technical Measures to Reduce Noise Emission from Trucks and Buses above 3.5 t and Their Influence on Various Operating [illegible] and Costs (Prices at 1.1.1972)

Type of Measure	Gr.	Expenditures DM	Idling	Starting noise dB(A)	Accel., 2.gear 1/3 nN dB(A)	Driving noise StVZO 3/4 nNmax dB(A)	Driving at const. speed 30km/hr dB(A)	Driving at const. speed 50km/hr dB(A)	Driving at const. speed 70km/hr dB(A)	Remarks
			31	14	8	6	33	8		[illegible]
Functional, sound proof, multisectional encasings of the motor space at the bottom facing the road and possibly on other sides.	I	750,- 890,-	1	0 - 2	0 - 1	0 - 2	0 - 2	0 - 1	0 - 1	
Alternative value for air cooled motors.		(1.200,-) (1.400,-)								
Automatic (Wandler) transmissions to reduce starter noises.	II	5.000,- - 8.000,-	1.700,- - 2.700,-	1.250 - 5 2.000 -	2.500,- 4 4.000,-	5	0 - 1	0 - 1	0 - 2	
		100	33 1/3	25	50 %	Wert				
Group 3 Measures requiring greater technological efforts										
Sound proof cool air circulation at the intake	II	600,- 990,-	-	0 - 2	0 - 1	0 - 2	0 - 1	0 - 1	0 - 1	
Sound proof cool air circulation at the exit of the motor space. For certain driver's cab this suggestion can only be realized to a limited extent, for some not at all.	II	800,- 1.310,-	-	0 - 2	0 - 1	0 - 2	0 - 1	0 - 1	0 - 1	

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4.10 Possible Technical Measures to Reduce Noise Emission from Trucks and Buses above 3.5 t and Their Influence on Various Operating Modes and Costs (Prices at 1.1.1972)

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Type of Measure	Grade	Expenditures DM	Acoustic efficacy on various operating modes: Idling	Starting noise dB(A)	Accel., 2.gear 1/3 n/nmax dB(A)	Driving noise StVZO 3/4 n/nmax dB(A)	Driving at const. speed: 30km/hr dB(A)	50km/hr dB(A)	70km/hr dB(A)	Remarks
% share in city traffic			31	14	8	6	33	8		
roup 2 Measures requiring time for development										
ound proofing improvements of uxiliary units, e.g. generator uel injection pumps, drives, tc.	III	200,- 250,-	0	1 - 2	1	1 - 2	[illegible]	0 - 1	0 - 1	
lternative values for air ooled engines		400,- 500,-								
mprovements of the engine. eduction of the surface eflection at some critical oints. Installation of sound roofing devices at the engine lock, cylinder head and other eflecting parts. or air cooled motors only of imited applicability, but ossible	III	900,- 2.100,-	0	5 - 7	4 - 5	5 - 7	[illegible]	[illegible]	3 - 5	

4.10 Possible Technical Measures to Reduce Noise Emission from Trucks and Buses above 3.5 t and Their Influence on Vehicle [illegible] (Prices at 1.1.1972)

Table 12/4

			31	14	8	6	33	8		% share in city traffic
Type of Measure	Grade	Expenditures DM	Acoustic efficacy on various operating modes							Remarks
			Idling	Starting noise dB(A)	Accel., 2. gear 1/3 nNmax dB(A)	Driving noise StVZO 3/4 nNmax dB(A)	Driving at const. speed			
							30km/hr dB(A)	50km/hr dB(A)	70km/hr dB(A)	
Enlarged cooling system without motor-driven ventilator, but with an electric ventilator.	III	360,-	0	0 - 2	0 - 1	0 - 2	0 - 1	0 - 1	0 - 2	
		650,-								
Alternative values for larger blower for air cooled motors.		500,- 800,-								
Completely sound proofed motor space as encasing with well functioning motor cooling. Possibly big constructional changes of the driver's cab required.	III	5.000,- 7.800,-	bedingt Konzeptänderung des Fahrzeuges 0	7 - 8	4 - 5	8 - 10	3 - 4	4 - 5	3 - 4	
Special Drives										
Hybriddrive with completely encased combustion engine inclusive of DM 20,000.- for battery that would have to be replaced every 30,000 km.	IV	35.000,-	0	8 - 10	6 - 7	10	4 - 5	4 - 5	3 - 4	

Summary of grades I-III in table 15

4.11 Possible Technical Measures to Reduce Noise Emission from Mofas and Mopeds and Their Influence on Various Operating Modes and Costs (Prices at 1.1.1972)

Table 13

Type of Measure	Grade	Expenditures DM	Idling	Starting noise dB(A)	Accel.,2.gear 1/3 nNmax dB(A)	Driving noise StVZO 3/4 nNmax dB(A)	Driving at const. speed 30 km/hr dB(A)	Driving at const. speed 50 km/hr dB(A)	Driving at const. speed 70 km/hr dB(A)	Remarks
Mofas			31	12	12	8	37	0		[illegible]
Mopeds			31	12	12	8	37	0		
Improved and enlarged intake dampening system with L_{max} less than 66 dB(A) at 7.5 m distance.	I	10,- 20,-	0	0 - 1	0 - 1	0 - 1	0	0	0	
Improved and enlarged sound dampening system with L_{max} less than 66 dB(A) at 7.5 m distance.	I	10,- 25,-	0	0 - 1	0 - 1	0 - 1				
Sound dampening devices on auxiliary units, e.g. motor casing, drive chain,etc.	I	20,- 50,-	0	0 - 1	0 - 1	0 - 2	0 - 2	0 - 1	0 - 1	
Functional, sound proof, multisectional, light and removable motor encasings or use of sound proofing devices within the framework of constructional possibilities.	II	65,- 175,-	1	0	0	0 - 2	Diese Maßnahme ist nur nach eingehend suchungen der Hersteller bei einigen Fa typen möglich.			

Summary in table 16

4.12 Sound Proofing Measures for Light Motorcycles and Motorcycles

Price List 1.1.1972)

Type of Measure	Grade	Cost for the vehicle DM	Idling	Starter Noise dB(A)	Acoustic Effect on Various Operating Modes					Remarks
					Accel. 2. gear, 1/3 nN max dB(A)	Driving noise StVZO 3/4nNmax	Driving at Constant Speed			
							30km/hr dB(A)	50 km/hr dB(A)	70 km/hr dB(A)	
Light Motorcycles			31	10	10	5	30	14	0	% Share in
Motorcycles			31	8	10	0	37	14	o	City Traffic
mproved and enlarged intake mpener L$_{max}$ less than 70 (A) Light motorcycles ss than 78 dB(A) motorcycl.	I	10,- 10,- 20,- 35,-	0 - 2	0 - 1	0 - 1	0 - 2	0 - 1	0 - 1	0 - 1	
proved and enlarged exhaust mpener max less than 70 dB(A)Lmc less than 78 dB(A)motcyc	I	10,- 15,- 25,- 40,-	0 - 2	0 - 1	0 - 2	0 - 3	0 - 1	0 - 1	0 - 1	
asures to reduce noise flection from the surface the motor and auxiliary its, e.g. drive, etc.	I	45,- 60,- 90,-150,-	0 - 2	0 - 1	0 - 1	0 - 3	0 - 1	0 - 1,5	0 - 2	
ctional, multisectional, und proofing motor casings thin constructional possi- lities	II	180,-280,- 350,-480,-	0 - 3	0 - 2	0 - 1	0 - 2	0 - 1	0 - 2	0 - 2	

This solution is not possible for some types of vehicles for technological reasons

mmary of grades I&II in ble 16

Table 14

intake noise dampeners and that manipulation for motor cycles with 2-stroke motors is especially easy. The suggested improvements and the required cost would ensure in any case sound dampeners that would follow the level of the motor noise over the whole range of revolutions, or lie below that by at least 4-5 dB(A) at high revolutions. The degree of feasibility is high in every case and the cost factor is advantageous.

5.1.3 Disengageable Ventilators (Visco-Luefter)

The following considerations form the basis of the measure described:

1. Extensive testing for passenger cars has shown that in urban areas the ventilator need be in operation only 10% of the total driving time to provide complete cooling of the motor.
2. For trucks the required time is considerably higher. It amounts to 50-70% of the time since for utility vehicles the maximal motor output is necessary, also in the city, much more often. The noise generated by the ventilator played a few years ago a considerable role. Its noise level was always equal or higher than the motor noise at high revolutions. Many a measure to reduce the overall noise level was offset by the ventilator level. For this reason the development of quiet ventilators was undertaken aggressively over the last few years. At the present state of technology asymmetric ventilators made from man-made materials, as well as quiet axial fans, are available the partial noise of which rarely exceeds the mechanical noise of the motor. Another important fact is that 4% of the motor output is required for the operation of the ventilator, especially at high revolutions. Therefore, engineers should be interested in reducing the demand by the cooling installation which can be achieved by complete turning

Table 15

Summary of the Results of the Survey "Costs for Modifications of Vehicles to Reduce Noise Emission". Summary Representation of Expenditures for Vehicles for Specified Measures, Effect on the Noise Level of Essential Operating Modes in City Traffic.

Cost in DM — Acoustic Effect of Improvements on Certain Operating Modes in dB(A)

		Leerlauf d	Anfahren b	1/3 n(Max)	StVZO	30 km/h	50 km/h	70 km/h
a [illegible] W. 100 [illegible]	Mittelw.-techn. g (1) mögl. Verbesserg. (2)	$56^{+7,5}_{-9,5}$ / 0-5 62^{+12}_{-3}	$70^{+10}_{-5,5}$ / 2-5	$75^{+5,5}_{-1,5}$ / 2-[illegible]	$73^{+5,5}_{-11}$ / 2-7	$61^{+7,5}_{-4,5}$ / 1-3	$70^{+6}_{-3,5}$ / 0-2	$74^{+5,5}_{-4,5}$ [illegible]
	Stufe I DM 3[illegible]0.- DM [illegible]00.-	0-3	0-3	0-5	0-[illegible]	0-2	0-2	[illegible]
		h Rechenbeispiele s. Teilstudie A. 3 Abschnitt A 4,1 Tabelle A 6						
	Stufe II DM 3[illegible]0.- DM 4[illegible]0.-	[illegible]	4-6	3-4	[illegible]	[illegible]	[illegible]	[illegible]
		h Rechenbeispiele s. Teilstudie A. 3 Abschnitt A 4,1 Tabelle A 8 u. A 9						
	Stufe III DM [illegible]00.- DM 2050.-	0-5	2-5	1-3	[illegible]	0-3	0-1	[illegible]
		i Die Werte der Stufen I bis III können in der Wirkung nur teilweise addiert werden						
b [illegible] <3,5 t [illegible] 200-204	Mit elw.-techn. g (1) mögl. Verbesserg. (2)	56^{+5}_{-5} / 0-6 $56^{+6}_{-6,5}$	$74^{+6}_{-8,5}$ / 3-5	$75^{+7}_{-3,5}$ / 2-[illegible]	$81^{+2,5}_{-2,5}$ / 5-6	70^{+2}_{-2} / 2-4	$73^{+1}_{-2,5}$ / 1-2	$76^{+1}_{-1,5}$ / 0-2
	Stufe I DM 460.- DM 720.-	0-1	0-3	1-3	0-3	0-2	0-2	0-2
		h Rechenbeispiele s. Teilstudie A. 3 Abschnitt A 4,2 Tabelle A 11						
	Stufe II DM 1130.- DM 1550.-	0	3-5	3-4	4-6	0-1	0-1	0-1
	Stufe III DM 4850.- DM 7530.-	0-5	6-7	6-7	5-7	0-1	0-1	0-1
		i Die Werte der Stufen I bis III können in der Wirkung nur teilweise addiert werden						
e [illegible] >3,5 t [illegible] 300-339	Mit elw.-techn. g (1) mögl. Verbesserg. (2)	$66^{+5,5}_{-6}$ / 0-8 $61^{+6,5}_{-8}$	$83^{+5}_{-7,5}$ / 5-9	$86^{+5,5}_{-11,5}$ / 5-8	87^{+4}_{-3} / 5-7	$80^{+6,5}_{-6}$ / 4-5	$84^{+5}_{-5,5}$ / 3-4	$86^{+6}_{-3,5}$ [illegible]
	Stufe I W L DM 1600.-, 1930.- DM 2000.-, 2500.-	0-4	0-3	0-3	1-2	0-2	0-2	0-2
		j Spezifische Kostenhinweise s. Teilstudie A. 3 Abschnitt A 4,2						
	Stufe II DM 3100.- DM 5000.-	0	1-3	1-3	2-4	0-2	0-2	0-2
	Stufe III W L DM 6 50.-, 6 700.- DM 10400.-, 11 200.-	4-8	4-5	2-4	4-6	2-4	1-3	0-1
		i Die Werte der Stufen I bis III können in der Wirkung nur teilweise addiert werden						
	Stufe IV DM 35 000.- DM 48 000.-	4-6	10-11	10-12	8-10	4-6	4-7	0-3
		k Stufe IV ist unabhängig zu betrachten						
f [illegible]	Mittelw.-techn. g (1) mögl. Verbesserg. (2)	$59^{+0,5}_{-1}$ / - dto	$73^{+1,5}_{-1}$ / -	$72^{+2,5}_{-1,5}$ / -	$76^{+1,5}_{-2}$ / -	$68^{+1,5}_{-2}$ / -	74^{+2}_{-2} / -	Werte für Hybridbus $73^{+1,5}_{-2}$ - l

Wert (1) = 7,0m seitlich gemessen m
Wert (2) = 7,0m nach hinten gemessen n

W = wassergekühlt o
L = luftgekühlt p

Keine Vorschläge zur Geräuschminderung für Elektrofahrzeuge q

[illegible] Stadtmodell - [illegible] Teilstudie I.3.

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Table 18

Summary of the Results of the Survey "Costs for Modifications of Vehicles to Reduce Noise Emission". Summary Representation of Expenditures for Vehicles for Specified Measures, Effect on the Noise Level of Essential Operating Modes in City Traffic.

Cost in DM Acoustic Effect of Improvements on Certain Operating Modes in dB(A)

		Leerlauf a	Anfahren b	1/3 n(NMax)	[illegible]	20 km/h	25 km/h
s Mofas Nr. [illegible]	Mittelw. techn. (1) g mögl. Verbesserg. (2)	$5?^{+2}_{-2}$ $5?^{+2}_{-2}$ / 0-2	$66^{+0,5}_{-7}$ / 0-2	$60^{+0}_{-0,5}$ / 0-2	60^{+0} / 0-2	$66^{+0,5}_{-7}$ / [illegible]	[illegible]
	Stufe I DM 40.- DM 95.-	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		j * [illegible]pezifische Kostenhinweise s. Teilstudie [illegible]					
t Moped Nr. 500-503	Mittelw. techn. (1) g mögl. Verbesserg. (2)	58±2 55±2 / 0-2	69^{+2}_{-2} / 0-2	$71^{+2}_{-2,5}$ / 0-2	$7?^{+?}_{-?}$ / 0-2	20 km/h $61^{+?}_{-2}$ / 0-1	30 km/h [illegible]
	Stufe I DM 40.- DM 90.- *	0-2	0-2	0-2	0-2	0-1	0-1
	Stufe II DM 85.- DM 1[illegible].-	0-2	1-2	1-2	1-2	0-2	0-2
		i Die Werte der Stufen I und II können in der Wirkung nur teilweise addiert wer[illegible]					
u Kleinkrafträder Nr. 600-[illegible]	Mittelw. techn. (1) g mögl. Verbesserg. (2)	$6?^{+1,5}_{-2}$ / 0-3 min (3)	77^{+3}_{-2} / 0-2 (2)	$73^{+2,5}_{-6,5}$ / 0-2 ([illegible])	$79^{+2,5}_{-3}$ / 0-2 (2)	30 km/h $70^{+5}_{-3,5}$ / 0-2 (4)	50 km/h $73^{+?}_{-3}$ / 0-2 (4)
	Stufe I DM 65.- DM 135.- *	0-3	0-2	0-1	0-2	0-1	0-1
	Stufe II DM 180.- DM 350.-	0-3	0-2	0-2	0-2	0-1	0-1
v Motorräder Nr. 700-708	Mittelw. techn. (1) g mögl. Verbesserg. (2)	$56^{+4,5}_{-7}$ 55^{+7}_{-6} / 0-3 (2)	$77^{+5,5}_{-6}$ / 0-2 (5)	78^{+10}_{-5} / 0-2 (3)	$8?^{+3,5}_{-4,5}$ / 0-2 (3)	$69^{+3,5}_{-7,5}$ / 0-2 (5)	73^{+4}_{-3} / 0-1 (5)
	Stufe I DM 110.- DM 225.- *	0-3	0-2	0-2	1-2	0-1	0-1
w Motorräder	Stufe II DM 280.- DM 480.-	0-3	0-2	0-2	1-2	1-2	1-2

x Für Kleinkrafträder und Motorräder geben diese Werte die erforderliche Verbesserung an, wenn man annimmt, [illegible] Fahrgeräusch 6 dB(A) > Sollgeräusch ist, bzw. 70 und 72 dB(A) beträgt. Nach Ansicht des Verfassers und [illegible] es aus heutiger Sicht keine technischen Maßnahmen, die für Kleinkrafträder und Motorräder die Werte [illegible] setzen könnte, da Lösungen, wie Automatik und wirksame Motorverkleidung praktisch ausscheiden.

Kostenauswirkung pro Stadtbewohner und pro Stadtmodell - [illegible] s. Teilstudie I.3

y *) sind nicht an jedem Typ realisierbar

z Wert (1) - 7,0 m seitlich gemessen

Wert (2) - 7,0 m nach hinten gemessen

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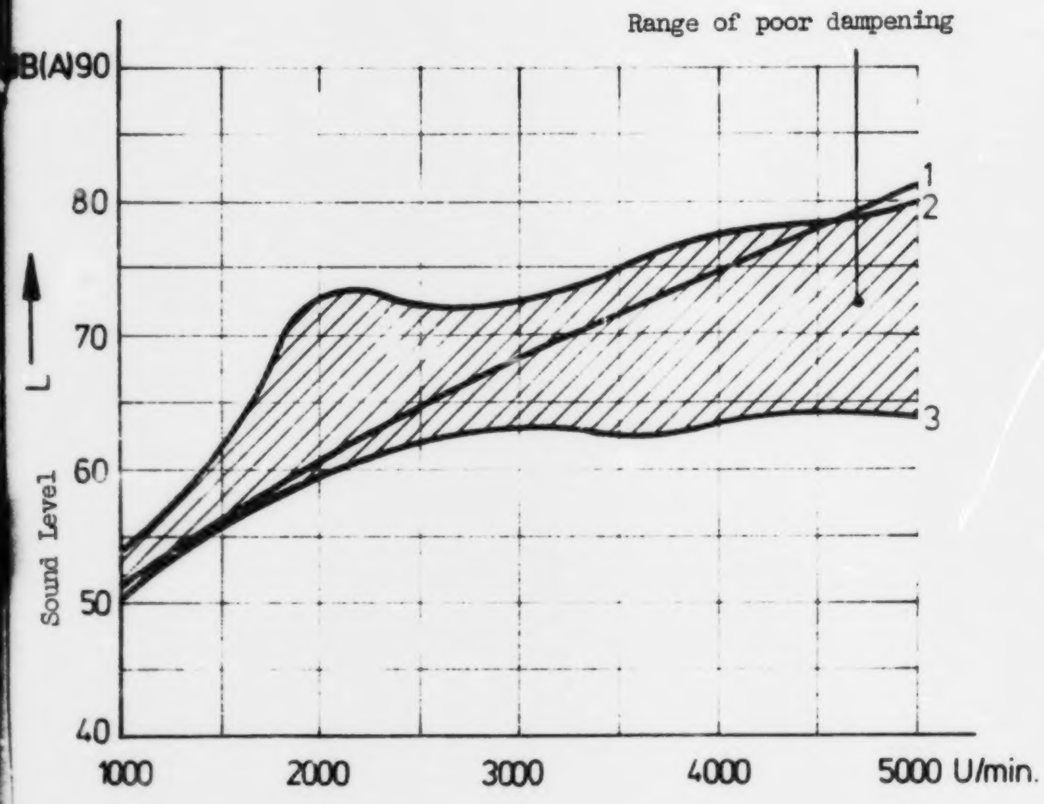
The Dampening Filter and Its Effect, tested at a Distance of 7.0 m

Type of vehicle: all categories.



1 Motor noise without exhaust

2 With Air Filter Manipulated (example)

3 With air filter

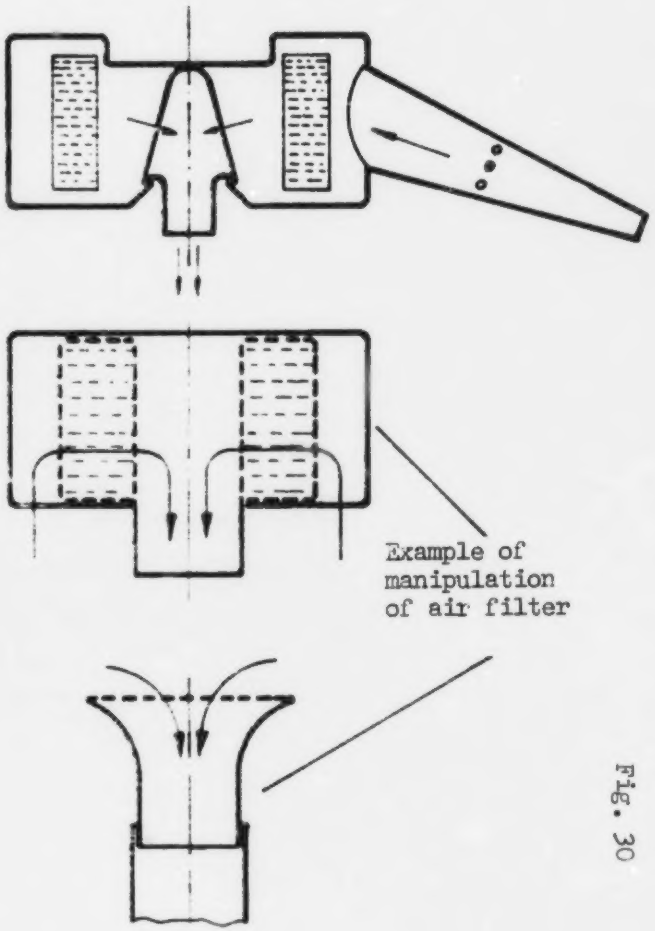

Example of manipulation of air filter

Fig. 30

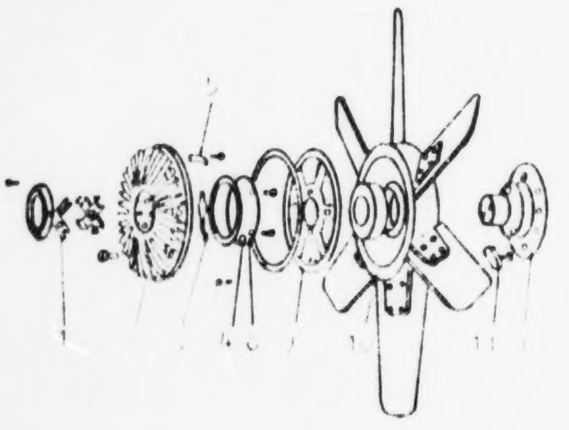
See Publication **MANN** Dampening Filter

Key to tables 15 and 16.

a) Idling
b) Start
c) Passenger cars no. 100-152
d) Trucks below 3.5 t no. 200-204
e) Trucks above 3.5 t no. 300-319
f) Electric Buses no.800
g) Average value and potential technological improvement
h) Examples for calculations, see part A.3 Section A 4_a1 Table A 6
i) Values of grades I-III are only partially additive in their efficacy
j) Specific suggestions as to expenditures see part A.3 section A 4_a2
k) Grade IV has to be considered separately
l) Values for Hybridbus
m) Value (1) = 7.0m measured sideways
n) Value (2) = 7.0m measured to the rear
o) Water cooled
p) Air cooled
q) No suggestions to reduce noise for electric vehicles
r) Expenditure per resident and per city model-building element as per partial study I.3
s) Mofas no. 400-402
t) Mopeds no. 500-503
u) Light motorcycles no. 600-603
v) Motorcycles no. 700-708
w) Motorcycles
x) For Light motorcycles these values indicate the required improvement, provided that the driving noise exceeds the rolling noise by 6 dB(A), i.e. amounts to 70 and 72 dBA(). In the opinion of the author and of the VFM there are no technological measures available today that would noticeably reduce the values for light and normal motorcycles, since solutions as automatic transmission and motor casings are practically not realizable.
Expenditures per resident and per city model-building element as per partial study I.3
y) not possible for all types
z) Value (1) = 7.0m measured sideways
Value (2) = 7.0m measured to the rear

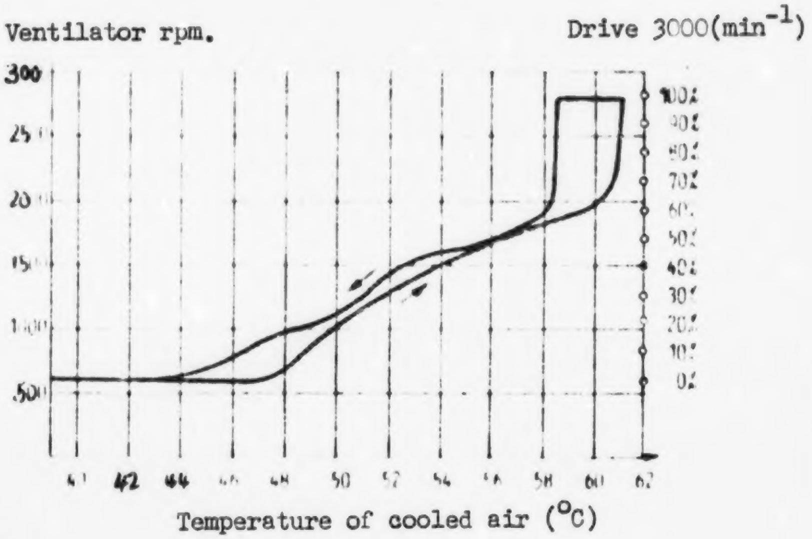
Fig. 31

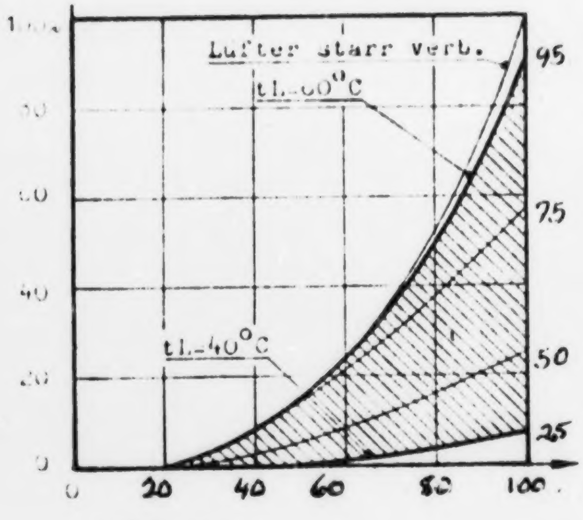
The Visco-Ventilator and Its Efficacy



1. Bimetalelement
2. Tripping Pin
3. Valve Lever
4. Borehole Pump
5. Oil Wiper
7. Valve Cover
8. Disc
9. Drive Disc
10. Clutch Cone

Regulation of the Visco Ventilator Clutch over the air temperature for constant rpm of the motor.





Ventilator performance as a function of the motor (wave) rpm.

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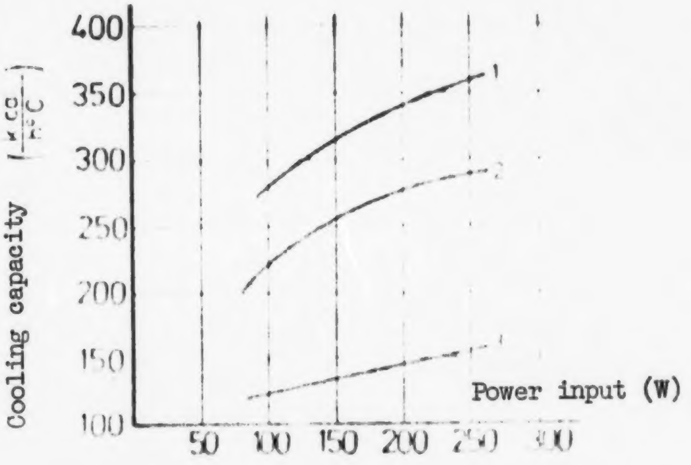
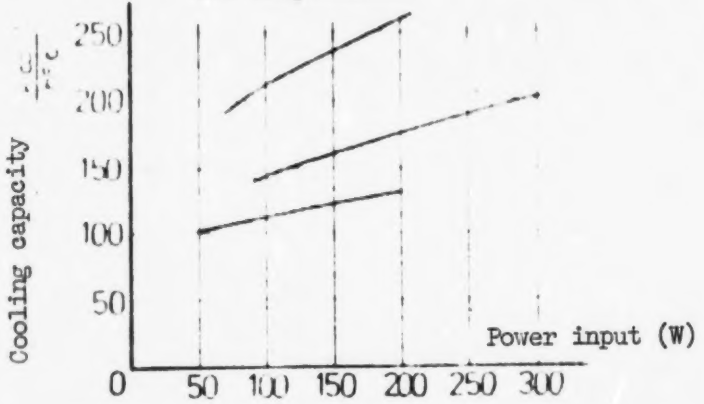
Fig. 32

The Electric Ventilator and Its INstallation

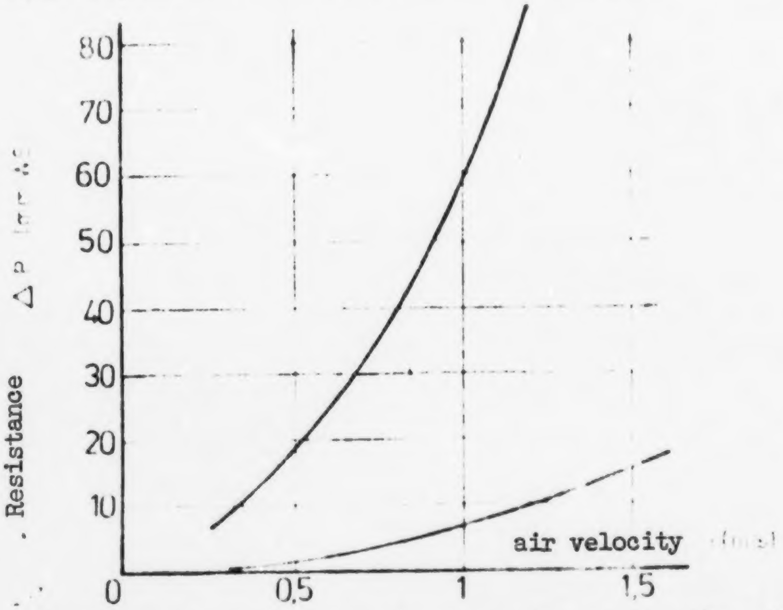
Type of vehicle: all categories



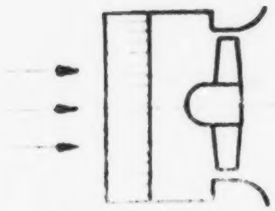
Ventilator performance as a function of its disposition



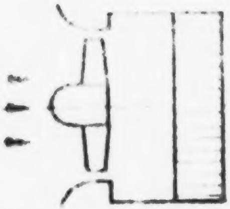
Power requirement as a function of the diameter



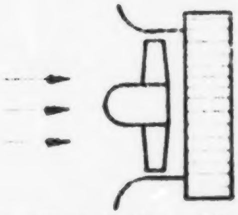
Resistance to ventilator as a function of its disposition



1 Ventilator behind the cooler



2 Vnetilator in front of the cooler



3 Vantilator directly in front of the cooler

siehe auch
Techn Inform BOSCH

off for a certain time or by reducing the number of rotations of the ventilator for a considerable portion of the total drivign time. Especially for trucks the Visco-Luefter is in use that can be guided by various parameters (temperature of the circulating water, outer temperature, load, etc.) In addition to a saving of motor output, a reduction of the motor noise at higher speeds by 2-3 dB(A) is sometimes noticeable. Fig. 31 shows the picture of a Visco-Ventilator. The diagram instructs about the range of its output. From a functional-technical point of view the Visco-Ventilator is completely developed. The economic factor is not quite as advantageous as for intake and exhaust sound dampeners.

5.1.4 Independent Motor Cooling

This system is in the developmental stage and certainly suited to be considered in future new developments. It proceeds from the premise that the cooling capacity is increased (sometimes as much as doubled) and a direct feed performance by the motor is abandoned. (2)

In special cases, i.e. on very hot days or for mountain driving an electrical ventilator is provided that running for longer times and with lower electromotor output is perfectly capable to provide the cooling that had been done up to now by the cooling ventilator. The power taken from the battery can be provided in passenger cars by a somewhat larger battery, as well as the required supplementary charge energy from an appropriately installed alternating current generator.

For utility vehicles this system is not applicable in the same way. Enlarged cooling is possible only in especially difficult cases, some times the front parts of the frame would have to be reconstructed to permit this kind of solution. It would have the advantage, however, of considerably larger cooling surfaces whereby the broad but lower front cooler that covers nearly the entire width of the vehicle, appears to the manufacturers perfectly feasible. Certainly electro-coolers are not sufficient as supplemental cooling so that in these cases the Visco-ventilator represents the only suitable installation. If the electrical capacity of the utility vehicle is enlarged by special measures (enlarged generator) and a larger battery, 2-3 electro-ventilators and a broad cooler could suffice to cover the cooling requirements. Details would require the cooperation of the manufacturers with experts from firms specializing in cooling systems and would have to be studied, tested and decided upon from case to case. Fig. 32 shows the construction of an electro-ventilator onto a cooler.

5.1.5 Utilization of Automatic Gears

Noise measurements on vehicles have shown that in all cases those equipped with automatic gear generate noises by 5-7 dB(A) lower than the same vehicles equipped with standard shift, be it for starting, partial acceleration or at the type inspection. Neglecting for the moment the very expensive measure to totally encapsulate the motor, of all measures examined the automatic gear shift has the most advantageous effect on noise generation during acceleration. Automatic gear shift does not only influence noise generation but also facilitates operating the vehicle which enhances traffic safety. Therefore, the expenditures for automatic gears can only partially be charged to the battle against noise. About the exact percentage opinions may vary. Values of 25, 33.3 and 50% were listed in the tables to permit various cost estimates. The evaluation in this partial study used a value of 33.3%.

Automatic gear shift avoids pushing the gears to the maximal number of revolutions within the city and thereby diminishes the sharp noise increases during partial acceleration. This only applies, ofcourse, when the automatic shift is in the proper position for city driving (drive) and no manipulations of the shift lever occur. It can also be set into lower gears. In this case the noise generation of the vehicle worsens and approaches that of a standard shift. It must be pointed out that the socalled "kick down" for acceleration with the full load functions differently for different gears depending on the construction. For various automatic gears the kick down position causes only a slight noise increase of about 2-3 dB(A) so that the measured values remain below those for standard shifts. For some types, however, the kick down position caused a noise increase that exceeded that of standard gear shifts. Such phenomena depend on the construction and could be eliminated if the noise generation they cause were considered. The technical safety of automatic gear shifts is reached to the fullest today and their use increases steadily on the European market. It will take probably 10-15 years, however, before the American level is reached whereby 75-80% of all vehicles are equipped with automatic shifts.

The cost factor for an automatic gear shift exhibits still advantageous values. It is to be anticipated that automobile manufacturers, in recognition of the advantages of automatic gears from the view point of noise generation, will make more of a point in their advertisements.

Among utility vehicles automatic gears are not widely used. This is so because automatic gears for utility vehicles would cost many times the price of the same for passenger cars because of the lower number produced and because of the different characteristics of the moment of rotation for Diesel motors. An exception constitutes perhaps the automatic solution for light trucks which could perhaps be taken over, with some modifications, from the passenger cars. As a result of these modifications their value increases by 100% compared with passenger cars. Tests have shown that for trucks also a noticeable effect of about 4-5 dB(A) can be achieved during acceleration with automatic gears. This value reduces the outer noise considerably.

Automatic gears of standard construction have not been used for motor cycles because of the high cost.

Nearly all Mofas are equipped with a mechanical two-gear automatic with centrifugal clutch. As a result their noise characteristics make them the quietest vehicle on the market. Avoiding manipulations of the intake and exhaust systems these vehicles generate no more than 68 dB(A) in any driving mode. This is a value that hardly disturbs, objectively, but that subjectively still needs improvement and that appears perfectly possible. It must not be overlooked that the characteristic of this noise lies in the middle frequencies and that therefore a noise level of 68 dB(A) can be experienced by some as more annoying than 71-73 dB(A) at lower frequencies.

Installation of fully automated gears for motor cycles was extensively discussed with the manufacturers and the association of the bicycle and motor cycle industry. A foreign machine with an automatic three-gear shift exists on the market, is however considered not fully developed and dangerous at the start. All manufacturers agree that for technical reasons light motor cycles and motor cycles would need an automatic clutch in order to satisfy traffic safety regulations. Without such a clutch the driver could turn over in case of some motor damage or a stuck piston that could cause an excessive breaking action. The manufacturers' remarks on cycles were interesting. They said that for power above 3 HP the automatic centrifugal clutch of the Mofas could not be used because they would not function safely. They also pointed out that automatic gear shifts are too expensive in terms of the overall cost of cycles, in contrast to passenger cars, that their development had not been pushed for this reason. The young drivers also wanted a vehicle that demanded as many gears to be manipulated as possible. Light motor cycles have sometimes as many as 6 gear shifts. The author is of the opinion that these questions need further discussions with the manufacturers and the associations. Changes in taxation according to cubic capacity might permit to construct vehicles of lower maximum rotations and larger cubic capacity and equip these with a simplified, appropriate automatic shift that would reduce the noise generation to a level that would be less disturbing than the present one. In any case the market- and competitive situation is going to be decisive.

5.1.6 Improvements of the Motor Noise and of the Auxiliary Devices

This point deserve special attention. There is no doubt that the many devices driven by the motor, such as the generator, the fuel injection pump, the gears, the water pump, the starter, etc. contribute to enhance the mechanical motor noise. Noise testing of such individual devices shows that their noise level can at ceratin speeds surpass that of the motor. Research on these parts has already been done and today quieter devices can be installed.

Engine manufacturers endeavor, motivated by their own intensive research on the motor, to develop quieter auxiliary devices. Further technical improvements of such auxiliary devices can greatly contibute to the reduction of the overall noise. This not only applies to Otto-motors but also to Diesel-motors. Such effects are slighter for the motors of cycles.

The sound emanating from parts of the engine that lie outside of the motor is considered part of the surface reflection. This reflection determines in the last analysis the level of the mechanical engine noise. Causes of these reflections are the gas-kinetic processes within the engine and the transfer of the body noise onto other parts of the motor and the crank gear. Different parts of the motor begin to resonate within certain speeds and reflect in this range higher noise levels. Measurements of body sounds or scanning with microphones at very short distances permit to determine maxima and minima of such reflections whereby it was surprisingly found that even surface noises reflect, that are not in direct connection with a power transfer. Experience teaches that for nearly all engines the cylinder head cover, the oil pan, the cover of the clutch casing, the gear casing and many other points at the surface are inclined to give maxima. Through systematic research noticeable improvements can be obtained, sometimes by increasing the rigidity, changes in materials, especially by interfering with the transmission of body sounds (for instance through reinforced seals). These measures do not always help. In such cases a reduction in body reflection can be achieved by installing double walls or adapters close to the surface and in connection with appropriate absorbing materials or sometimes even without the latter. Such measures have the advantage compared to other secondary sound casings that the mounting of the engine is preserved, the cost is smaller than for sound encasings, and the reach of the engine in case of repair is preserved.

In connection with other suitable measures the results suffice to reduce the noise to a level that is economically acceptable. This could also be achieved if, in connection with changed taxation, the cubic capacity of the engines were to be enlarged but the maximal number of revolutions reduced by about 1000 rpm compared to the present state.

It must be mentioned that development of such noise reducing measures requires time and that not every measure is presently ready for line production. As for the future it must be mentioned that such measures exhibit an advantageous cost factor and therefore a greater degree of feasibility than the usual secondary sound protection devices. These suggestions apply to Otto-motors, Diesel-motors and to a considerable extent also to the 2-stroke engines of motor cycles.

The close-range measurements done within the framework of this study on gear casings, cylinder heads, cooling vanes and exhausts, showed that the mechanical reflections of these motors are considerable. Suggestions for improvements were given to individual manufacturers by the author. It is questionable, however, whether they will be accepted because of competition.

It is most certain that suitable adapters, better sealing and interference with noise transmission of body sounds within the casing would result in improvements, especially of the subjective noise impression. But further research is required.

5.1.7 Secondary Noise Protection Measures

Mention must be made here of the casing of the engine, as well as the noise dampening air cooling at the intake and the exit side of the motor, covering of the engine space below, better sealing of the radiator cover, and, finally, of the entire functional engine casing. If these measures are ideal from a technical standpoint of noise reduction, their practical acceptance is difficult. Devices that can be installed into stationary motors with relative safety of operation require special consideration in a vehicle whereby resistance to vibrations, the danger from deposits from oil and gasoline and, as a result, fire hazards must be mentioned. Further it must be ascertained that the absorbing materials used are insensitive to rain, ice and snow. Other difficulties are the relative high costs and a durable installation. For passenger cars the permissible noise level in city areas can be achieved through good intake and exhaust systems, together with an automatic gear shift and other tuning- and dampening measures, so that for this category of vehicles installation of further, secondary sound protection devices within the engine space for the improvement of outer noise does not appear meaningful. It must not be overlooked that the testing stage at the present time is not sufficiently advanced to recommend such measures and that the cost factor is many times worse than for the measures discussed in section 5.1.6.

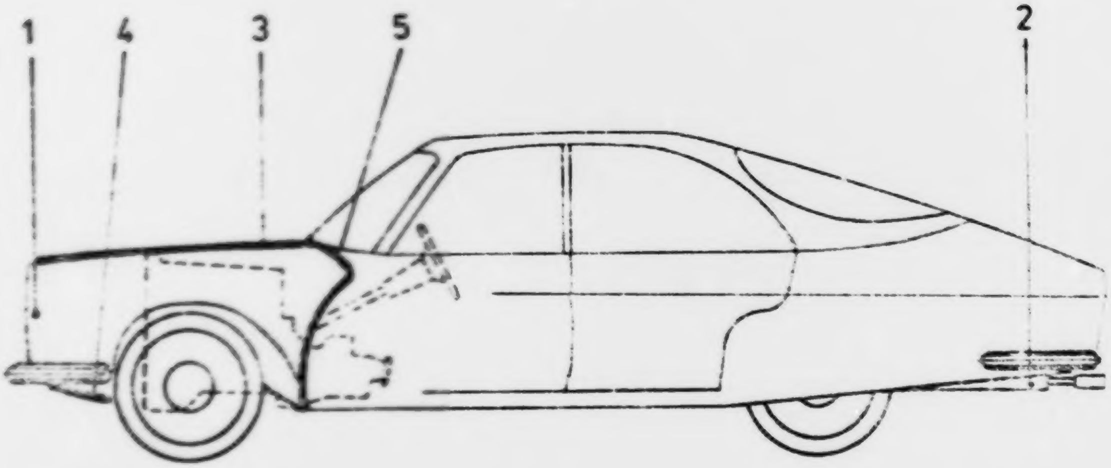
For motor cycles such secondary sound protection measures are nearly useless. Partial casings can be installed. However, such casings would have to be installed in a fashion that isolates them from the vibrations which is not always possible. To maintain the engine functional, external cooling would have to be installed which is difficult to realize in praxis.

For utility vehicles the installation of secondary sound protection measures is especially problematical for certain types of vehicles. (26) Casings of the engine space to reduce the inside noise are already partly in use, however, it must be remembered that the engine space of trucks is usually open at the bottom, regardless whether the motors are cooled by air or by water. Its encasing is difficult and could lead to disturbances in the cooling system. This is particularly true for vehicles with air-cooled

Fig. 33

Schematic: Distribution of Various Secondary Sound Proofing Measures on Vehicle : Grade 1, Partly Grade 2.

General example: in principle applicable to many types.



1. Area for improved intake-and ventilator noise dampener
2. Improved exhaust gas sound dampening system
3. Sound proof engine cover with absorption and supplemental rubber seals on the seams (Partially existing)
4. Functional sound proof multisectional lining of the motor space, also at bottom.
5. Special front wall insulation (partially available in line products)

Sketch of a System of a Motor Encasing Using as an Example the Water Cooled Truck Motor

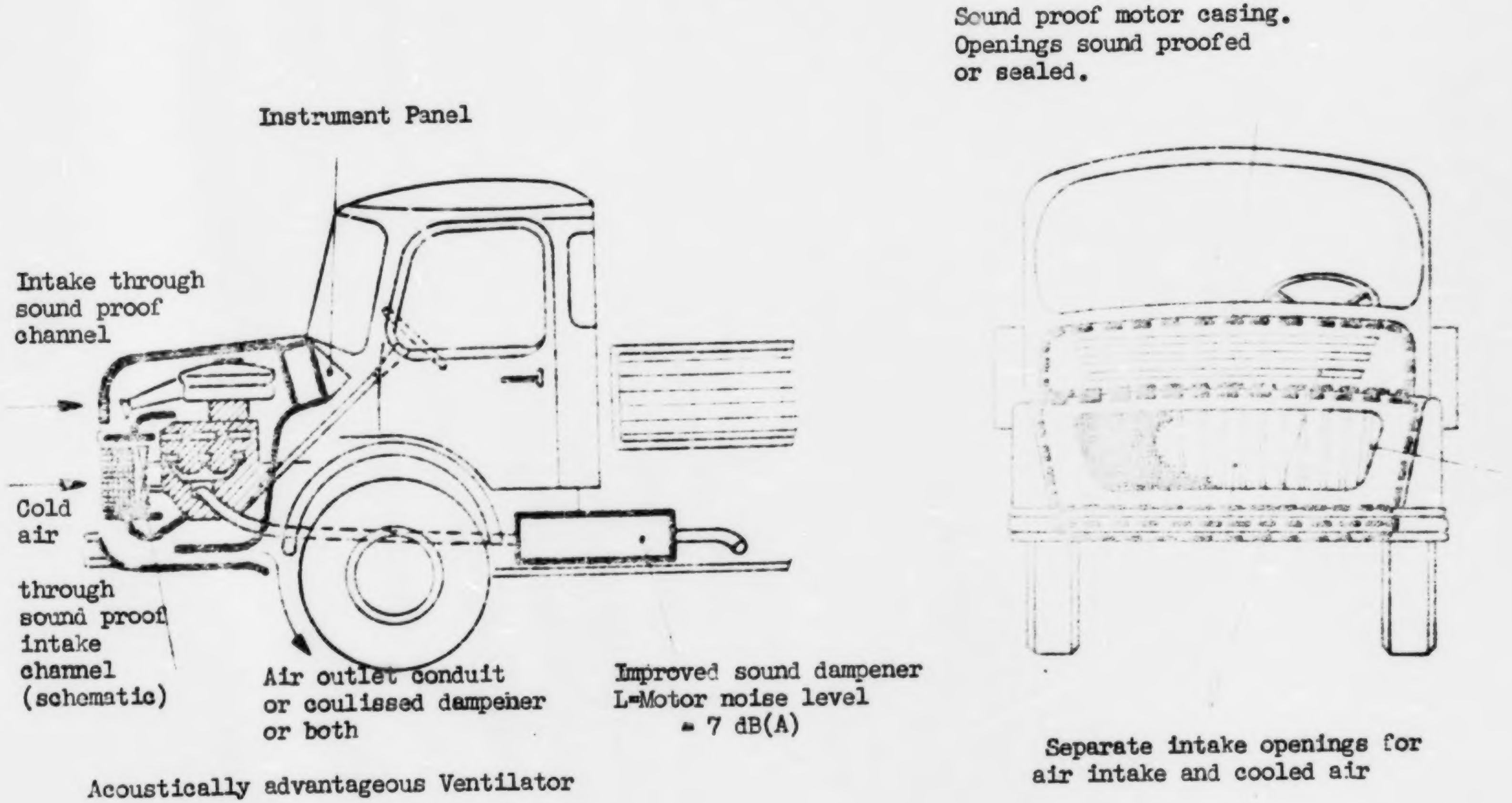

Instrument Panel
Intake through sound proof channel
Cold air
through sound proof intake channel (schematic)
Air outlet conduit or coulissed dampener or both
Acoustically advantageous Ventilator
Improved sound dampener L=Motor noise level = 7 dB(A)
Sound proof motor casing. Openings sound proofed or sealed.
Separate intake openings for air intake and cooled air

Fig. 34

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engines. Today's tiltable cab cannot be used in its present form in connection with an effective secondary sound protection system, as presently in the planning stage, and the truck manufacturers seem justified in stating that to realize a complete motor casing a whole new concept of this type of vehicle is needed. (26). Its construction would have to be such that normal as well as sound protected vehicles could be built based on one fundamental design which at present does not seem feasible for mass production. The economic factor for secondary sound protection measures is particularly disadvatangeous for trucks despite the fact that from an objective, technical standpoint secondary sound protection measures could contribute substantially to a reduction of the overall noise level. In summary it can be stated that sound protection measures require testing at the manufacturer's, that their adoption can be useful in certain instances, but that entire motor casings require more time to be developed. In any case the measures discussed in sections 5.1.1-5.1.6 should be given priority. Figs. 33 and 34 show schematically the placement of secondary sound protection measures in passenger cars and trucks.

5.1.8 Special Drives

Newspapers often report on drive systems of the future, the electric car, the steam driven car, or the Stirling motor (20, 23, 27, 30) or still other possible drives. It should be mentioned that these solutions are usually not suggested with a view toward noise protection but preferentially in connection with the problem of exhaust gases, and their possible adoption is being studied for that reason. It is beyond the scope of this study to discuss such possibilities in terms of noise protection; we therefore refer the reader to the literature for the steam driven car, the Stirling motor and the gas turbine (20, 23, 23a, 27, 30).

The electric car and the electro-hybrid drive have been examined for their acoustics (25). Our own measurements gave the expected results in terms of noise generation. At 50 km/hr the rolling noise determines the noise emission of this vehicle and at 70 km/hr noise levels of 78 dB(A) are reached. Nevertheless, these vehicles are quieter than trucks of comparable size by 8-10 dB(A). The peak level can be reduced through suitable measures and is, therefore, not as important as the noise generated by starts and acceleration at low speeds. In this range the electric car demonstrates its superiority and measured start-and acceleration noise levels are below the present state of Diesel-motors by about 10-12 dB(A).

Automatic transmissions in connection with partial casings can, however, reduce this difference considerably so that it can be stated, in summary, that the electric car has decided acoustic advantages but vehicles with Diesel-motors can approach their level and considerations of safety and operating costs are very much in favor of the Diesel-motor. The problem of the battery for electric cars has not been solved satisfactorily to-date. The electro-hybrid bus requires considerably higher expenditures so that it is doubtful whether it is going to be accepted as a solution to any large extent. It is possible that efforts to maintain clean air will decide this question.

When considering special drives the rotary wankel motor must not be overlooked. An assembly line produced car equipped with such a motor was also among those tested by us. Objectively it must be stated that the mechanical motor noise of this car was the lowest of all 53 passenger cars tested.

When equipped with a semi-automatic transmission this vehicle also had a good acceleration noise level. It was sometimes lower for other types of cars with a fully automatic transmission. But within the city these cars are just as quiet. In a special test it was determined that the mechanical motor noise of the wankel motor is advantageous at higher speeds. This does not exclude the possibility that further development of the piston motor will permit further noise reduction whereby engine noises of 74 dB(A) at 5,000 rpm already represent a level that is exceeded by the rolling noise.

5.2 Noise Reduction that Can Be Achieved after Adoption of the Technical Suggestions by Surveillance and Education

This point must be premised as follows: in section 3.5 it was pointed out that three main areas need special consideration: 1. technical surveillance, 2. handling of the car by the driver, 3. further technical developments. Noise reduction that can be achieved through consistent observance of the suggestions must be judged in the same way. Taking the present state of technology and the legal regulations of 1.1.1972 as point of departure, the following can be stated:

5.2.1 Technical Surveillance

If different legal regulations existed, such as suggested in sections 5.3.4 and 5.3.6, technical surveillance and police controls could eliminate 90-95% of all vehicles equipped with manipulated intake- or exhaust dampeners as well as those tuned up for increased output. Reduction of individual noise levels of 8-10 dB(A) could be anticipated. Even if only a small percentage of such cars (an estimated 2-3%) were picked up it would already be noticeable because loud vehicles are being judged as individual disturbances much more critically by pedestrians. Furthermore, noise generation of each vehicle could be controlled in the simplest manner at the bi-annual inspection, which is not presently possible.

Existing radar-squads of the police could be equipped with supplemental noise testing gear and thus be very effective in combatting noise.

5.2.2 Driver's Education

It is conceivable that through driver's education the piercing starting noises that are being observed for 30% of all drivers could be reduced by more than half. The same applies to the slamming of car doors, etc. whereby in individual cases noise reductions of 4-5 dB(A) are obtainable. Other individual factors, such as "sporty" driving and accelerating during idling (playing with gas pedals) are to be mentioned.

5.2.3 Further Technological Developments

These measures have an efficacy of practically 100%. Fig. 35 summarizes the measures for a noise reduction for the individual types of vehicles. It can be assumed that, neglecting automatic transmissions, 50% of the vehicles could be improved by 3-4 dB(A) in some areas. If automatic transmissions were to be installed the equivalence level L_{eq} which is determined decisively by the peak levels, could be reduced across the board by 4-5 dB(A), calculated for all vehicles. Both noise level reductions are not strictly additive. These noise level reductions would be noticeable in urban areas.

5.3 Suggestions for Legal Action and Building Codes

The extensive program for noise reduction represented in layouts 1 and 2 was a success. It was the basis for the extensive statements of this survey. We notice with satisfaction that some manufacturers have taken suggestions from this survey for their own investigations and introduced improvements of various parts with a view toward noise reflection. It has been demonstrated that the noise levels measured at the type inspection is not sufficient to characterize the acoustics of the vehicles in their entire range of operations. Nor does this noise level characterize the typical city traffic since full acceleration from 50 km/hr in second gear already leads to an exceeding of the speed limits. The attempt to determine a value characteristic of a given type that approaches the peak level permits, at low speeds, ample room for manipulations, especially for high start- and accelerating levels. (See also section 3.3). These levels are particularly disturbing in urban areas. On the other hand it is evident that the program for noise testing represented in layouts 1 and 2 could never form the basis for a type inspection. Also, measurements with recording instruments (noise level recorders, magnetic tapes, etc.) are not feasible for all vehicles, e.g. motor cycles. Nor could such test values be easily rechecked so that traffic controls by the police would be impossible. In an attempt to stipulate minimal measures, the following compromise is suggested:

5.3.1 Testing of Driving Noises

Categorizing of the vehicle should also in the future be done according to the StVZO and the testing procedures specified therein, in order to determine the maximal noise emission.

N. B. After adoption of the EG-guide line of February 9, 1970 into the German law these regulations should apply. The type value so measured must remain within the range of the specified tolerance levels. Operating conditions for vehicles with 5-gear drives and for vehicles with automatic transmissions should be further extensively discussed with experts. The author

Possible Noise Levelreductions during Acc. eleration (Peak Levels) Measured at a Distance of 7.5 m

Type of Vehicle: All Categories.

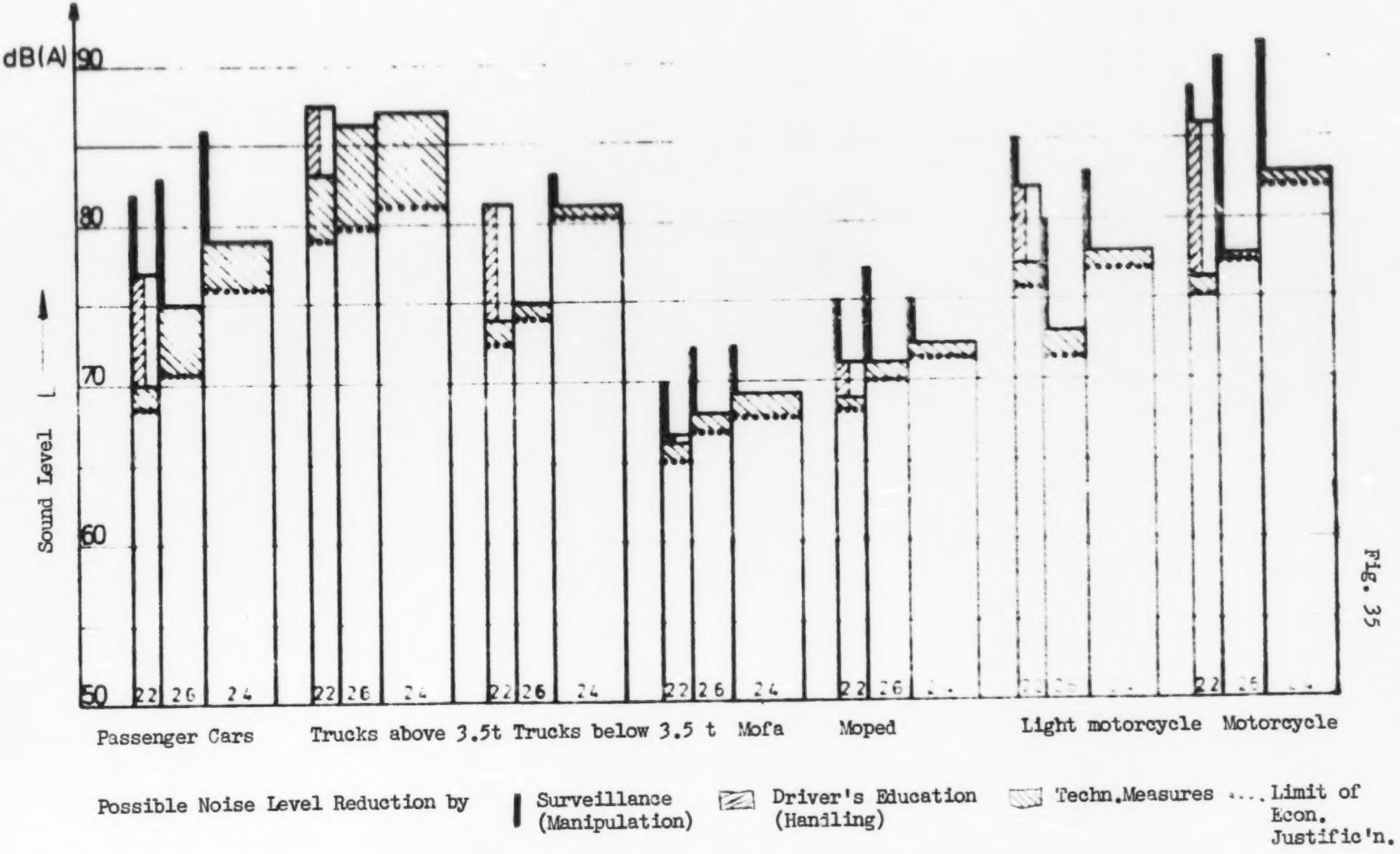


Fig. 35

holds the opinion that vehicles with 5- or more gears should basically also be tested in the second gear. Only when at the end of the testing track or during accelerating nN max is exceeded at the inspection the next higher gear should be permitted. For Diesel motors with constant speed control shifting into the next higher gear should only be permitted if the constant rpm have been reached at the end of the testing track. Details should be decided by a committee of experts.

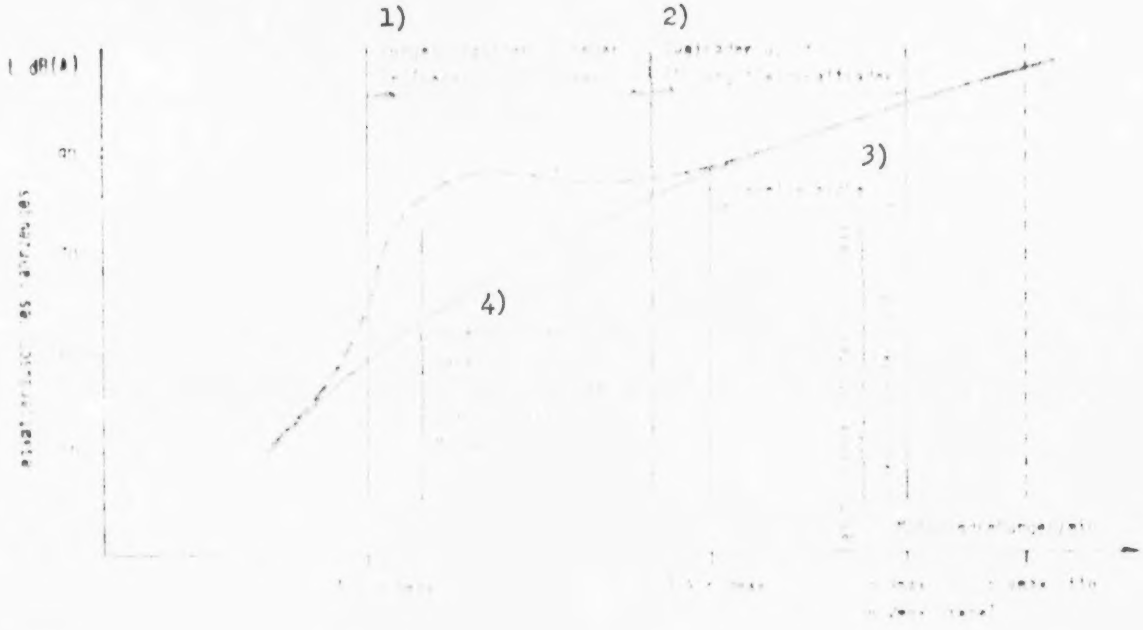
Automatic transmissions reduce noise emission. In the interest of technological progress lower tolerance values should be proscribed, maintaining normal driving conditions, for vehicles so equipped. It is anticipated that this would encourage the installation of these drives more than adaptation of driving conditions to a choice of lower gears while the same tolerance values are applied. The latter also represents a technically feasible solution but the author considers it less progressive.

5.3.2 Measurements of Acceleration from a Distance of 0.33 nN max.

A second measurement of accelerations should be done on the same testing track and under the same test conditions during which the vehicle is accelerated essentially in second gear but the initial rpm amount to only 1/3 of the maximal motor output without regard to the starting speed. A tolerance value should be fixed for this operating mode that should be lower than the specified maximal value for measurements from 3/4 nN max. Due to the very different characteristics of various types of vehicles the variations are very different. Suggestions can be obtained from the diagrams for the individual types of vehicles by comparing sections 2.4 and 2.6.

Fig. 36

Attempted Assignment of overall Driving Noises and Possible Test Ranges



1) Suggested new testing range 1/3 nNmax
2) Testing range StVZO (ISO) 4. gear passenger cars, cycles and trucks 5. gear for light motorcycles)
3) Dieselrange
4) Present testing range StVZO (ISO) 5. gear and automatic (passenger cars and heavy motorcycles

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For trucks with cross-country gears or drives in series choice of gears should be permitted for this measurement that allows to reach 3/4 nN max at the end of the testing track.

Fig. 36 shows the speed ranges covered by these tests.

5.3.3 Test of Starting Noise

Measurements of starting noises can be done in first gear and from a starting speed of less than 5 km/hr over a track of 10 m and the length of the car (see layouts 1 and 2 and section 2.7). Extension of the measurement over a testing distance of 20 m plus the length of the car leads for many types of vehicles to a forcing of the engine. Diagrams for all types of vehicles contain also suggestions for this test procedure. Comparing sections 2.4 and 2.7 suitable difference values can be obtained. A special determination of tolerance values would be necessary. It would require further investigations to determine whether such measurements should be subject to future type inspections. Suggestions in section 5.3.2 presumably already cover all essential effects influencing the starting process.

5.3.4 Control Measurements of Traffic Noise

This should fully replace the present static test from a distance of 7 m because of its exaggerated requirements on the test site and the disturbance level. In the interest of subsequent traffic control, measurements should be made from a distance of 50 cm or 1.0 m at an angle of 30-45°.

5.3.4.1 From the muzzle of the intake dampener or the front of the car

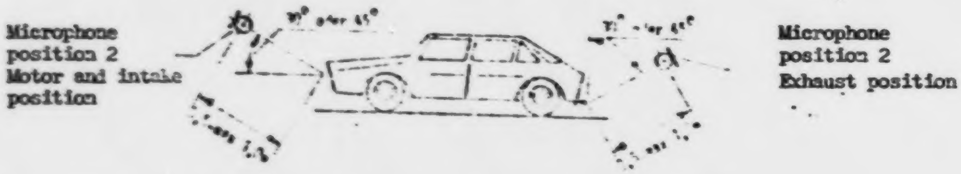
5.3.4.2 from the muzzle of the exhaust muffler, with 3/4 of maximal rpm or the intake- and exhaust noise should be measured at nN max.

For vehicles with rear motor, measurements are to be taken only at the muzzle of the exhaust muffler, for vehicles with upward exhausts at

Fig. 37

Suggestions for Test Control Measurements of Traffic Noises

Fig. 1 Positions of the Microphones


Microphone position 2 Motor and intake position
30° oder 45°
0,5 max 1,0
30° oder 45°
Microphone position 2 Exhaust position
0,5 max 1,0

N.B.: Other microphone positionings, e.g. for measuring point 1 90° rotated around the exhaust pipe axis, i.e. position of the microphone in horizontal plane to the muzzle of the exhaust below 30 - 45 ° inclination, or for measuring point 2 in horizontal plane constant distance from the road give similar and useful results.

Fig. 2 Positions of the Microphones Viewed from the Top with Different Positions of the Exhaust Pipe

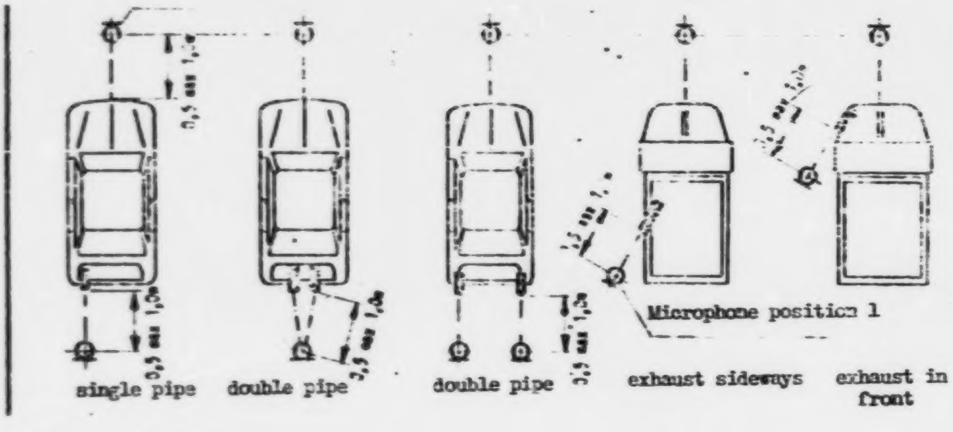
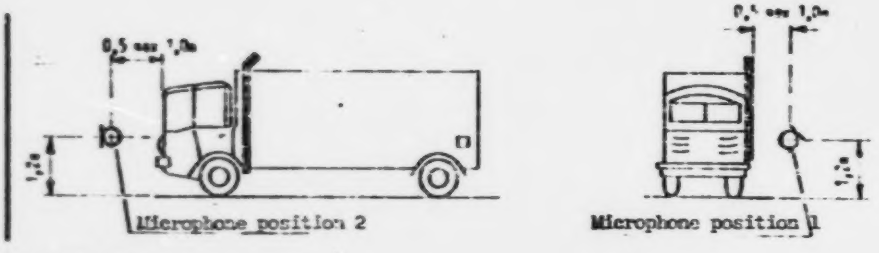

0,5 max 1,0m
0,5 max 1,0m
0,5 max 1,0m
0,5 max 1,0m
0,5 max 1,0m
0,5 max 1,0m
Microphone position 1
single pipe
double pipe
double pipe
exhaust sideways
exhaust in front

Fig. 3 Exhaust Pipe Upwards


0,5 max 1,0m
1,2m
Microphone position 2
0,5 max 1,0m
1,2m
Microphone position 1

Operating Modes:
Otto-motors: nN max (or 3/4 nN max) gas removal (decay process)
Motors with limited rpm : Peak value during acceleration of the motor to top rpm gas pedal fully depressed.

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distance of 1.0 m from that edge of the car that lies next to the exhaust, for motor cycles at the muzzle of the exhaust muffler and at the side of the engine block.

It is suggested to carry out measurements in such a fashion that after reaching 3/4 nN max-rpm or nN max the gas pedal be released suddenly. This way it is easy to measure peak levels that appear at 3/4 nN max or when the number of revolutions decreases (decay-procedure). (For details see fig.37)

An even closer approximation of measured to actual values could be made by determining the number of revolutions at 3/4 nN max (or nN max) by alternating activation of the gas pedals (a type of see-saw acceleration). The maximal value between idling and 3/4 nN max (or nN max) found in this type of examination should be regarded as independent of the speed. Measurements at nN max give more reliable results because of the greater distance from the disturbance level.

For Diesel-motors with constant speed control it is suggested for practical reasons (measurement of revolutions) to accelerate the engine rapidly to nN max. The peak noise level that occurs during rapid and complete depression of the gas pedals, independent of the speed, should be recorded as the measured value. The exact formulation of the test regulation should be done by a committee of experts.

5.3.5 Entries on Car Registrations

The values mentioned in section 5.3.1 and 5.3.2 should be entered on the car registration as driving noises 1 and 2, those mentioned in sections 5.3.4.1 and 5.3.4.2 as standing noises 1 and 2 so that they are available at all times for control purposes. Because of the short test distance the usual tolerances should be increased when determining possible influences on the level at 7.5 m. A value of 3-5 dB(A) seems to be required. Further tests should be done before stipulating these values. A correlation between tests from a short distance and the driving noise is often not possible for physical reasons, nor is it necessary.

5.3.6 Supplemental Constructional Regulations

In addition the following requirements for the development of intake and exhaust systems should be requested in a legally binding fashion:

5.3.6.1 In developing intake and exhaust systems resonance phenomena should be avoided through suitable technical measures. The values determined at the type inspection of these two driving noises must not, individually (intake or exhaust noise) exceed the overall noise by more than 1.5 dB(A). This means that the type valuation of intake and exhaust noises measured by themselves would have to be lower than the engine noise proper by about 4 dB(A). A suitable test procedure for an unequivocal proof of the factual situation is described in the Norm B 506 (FAMAK B5) sections 5.2.2 and 5.2.3. Actually a manufacturer's warranty of these specifications would suffice and supplemental tests at the type inspection could be dropped.

5.3.6.2 It is to be ensured through suitable constructional measures that the legally specified tolerance levels are observed within the principal inspection period (2 years). In case of damage or corrosion the car owner is required to have the damage repaired in short order (one week).

5.3.6.3 Sound dampeners for 4-stroke motors are not permitted to contain removable parts but must be sold as one solid unit.

5.3.6.4 Sound dampeners for 2-stroke motors with removable parts have to be constructed in such a way that when parts are removed a reduction in dampening may occur but the resulting overall noise level must not exceed the type value by more than 2-3 dB(A).

N. B. It appears possible from a technical standpoint to construct also 2-stroke dampeners in such a way that one part is solidly mounted and the possibility of direct cleaning is abandoned. Details would have to be stipulated in agreement with associations, manufacturers and the special committee "Noise Testing".

5.3.6.5 Exchangeable sound dampeners and tunings that can influence the noise level may be sold only if their type of construction has been approved. It must be ensured that with regard to noise emission, durability, quality and strength of materials the serial standard is, through these installations, at least maintained. A recognized, internationally standardized test procedure would be a prerequisite for technological progress (see also section 5.1.2). Uniform tests and controls could greatly contribute to a noise level reduction. The necessary conditions do not presently exist in all countries of the Europen Economic Community (no technological surveillance, no bi-annual main inspection).

5.4 Suggestions for Supplemental Measures

All measures of a controlling, educational or technological nature would be very much weakened were they not reinforced by supplemental measures. The following must be pointed out:

5.4.1 Regulation by Traffic Lights

Ever more light signals are being installed in urban areas. It happens that in certain situations they represent the only possibility to manage the large traffic volume. Since starts and accelerations are noisy operations and produce considerable exhausts it was to be investigated whether traffic lights could not be synchronized as a rule. In the morning hours and after 8 p.m. when traffic is light, regulation by traffic lights could be lifted. In places of light traffic the flow should not be interrupted artificially.

5.4.2 Urban Construction

About measures of urban construction see other sections of the survey. (Partial Study I.1.1)

Only road width, road surfacing, the influence of border construction, building gaps, building heights, the distance between house facades and the street, etc. will be discussed here.

5.4.3 Residential Buildings

Sound insulation of buildings has to be improved because by technical measures on the vehicles alone their noise levels cannot be reduced sufficiently so that in all cases, especially where the distance to the road is short, the level specified by medical experts can be reached inside. Suitable seconiary sound proofing measures, especially window constructions, are useful. For details see the partial study I.1.1 and I.3 section B.

6. Final Conclusions

6.1 Prerequisites for Protection from Traffic Noise

Effective protection of the environment against traffic noise in urban areas requires:

6.1.1 International Cooperation

6.1.2 Internationally uniform regulation of construction and taxation

6.1.3 Graded classification of vehicles and stipulation of uniform tolerance values for these categories

6.1.4 Improvement of technological and police controls for vehicle parts that influence the noise level decisively (intake filters, exhausts, tires)

6.1.5 Quieter driving habits of drivers (avoidance of excessive acceleration, unnecessary sounding of horns, etc) see section 3.2.

6.1.6 Uniform supplemental legislation in all countries, see section 5.3

6.1.7 Improved construction of cities, roads and buildings with a view toward sound proofing

6.1.8 Realization of feasible technological improvements of the individual vehicle, see section 4.8-4.12

6.2 Long-Term Results of the Survey

6.2.1 Extended testing programs cover all important operating modes typical for urban driving in a simple manner.

6.2.2 The state of technology exhibits large spreads for certain operating modes that could be considerably limited through suitable measures. Differences of up to 10 dB(A) are not rare.

6.2.3 To determine the economy new formulas were given for known calculations that take into account the requirements for sound proofing and essential physical factors. (Layout 5)

6.2.4 Mass-produced sports cars can reach the noise levels of other mass-produced cars when properly developed. Effective legal regulations have to restrict the inclination of drivers to develop a racing or "rally"- sound and to dismantle sound proofing devices or to tune up the engine.

6.2.5 Expenditures for sound proofing can vary widely. Internationally uniform regulations could minimize distortions due to competition. Exaggerated demands could lead quickly to exhorbitant costs and thereby considerably limit their potential reaslization.

6.2.6 Extensive measurements of outdoor noises and broad testing programs should be repeated every 5-7 years because the automobile technology changes and progress in other areas should be taken into account.

6.2.7 For nearly all vehicles an acceptable tolerance level can be achieved with reasonable expenditures. For trucks above 3.5 t somewhat more expensive casings may have to be considered, the general acceptance of which requires further reseach, especially concerning motor cooling.

6.2.8 For light or heavy motor cycles without speed limits no economically feasible solution appears to be developing to-date.

6.2.9 Further intensive research and development are needed on the sources of contributing noises.

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APPENDIX

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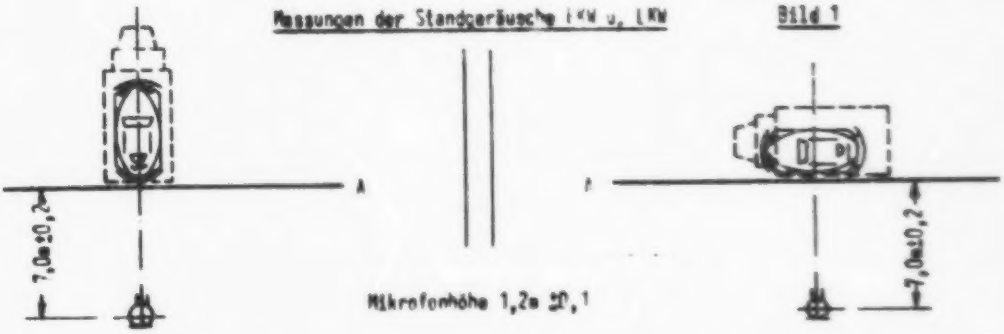
Layout 2 " 136 - 138
Layout 3 " 139 - 141
Layout 4 " 142 - 143
Layout 5 " 144 - 152

Layout 1

Extended Noise Testing Program for Outer Noise within the Framework of th EG-Survey for Passenger Cars and Trucks

1. Standing Noises

Microphone positioning 1	Microphone positioning 2
7.0 m to the rear	7.0 m to the left
1.1 normal door closing	1.11 normal door closing
1.2 door slamming	1.21 door slamming
1.3 start engine	1.31 start engine
1.4 alternating acceleration of the motor	1.41 alternating acceleration of the motor
1.5 as 1.4 with supplemental exhaust muffler	1.51 same as 1.41 with supplemental exhaust muffler
1.6 motor idling	1.61 motor idling



2. Driving Noises during Acceleration

2.1 starting the car with normal acceleration

2.2 rapid starting of the car (tires almost squeal)

2.3 acceleration with full gas in 2. gear from 20 km/hr

2.4 driving noise according to StVZO

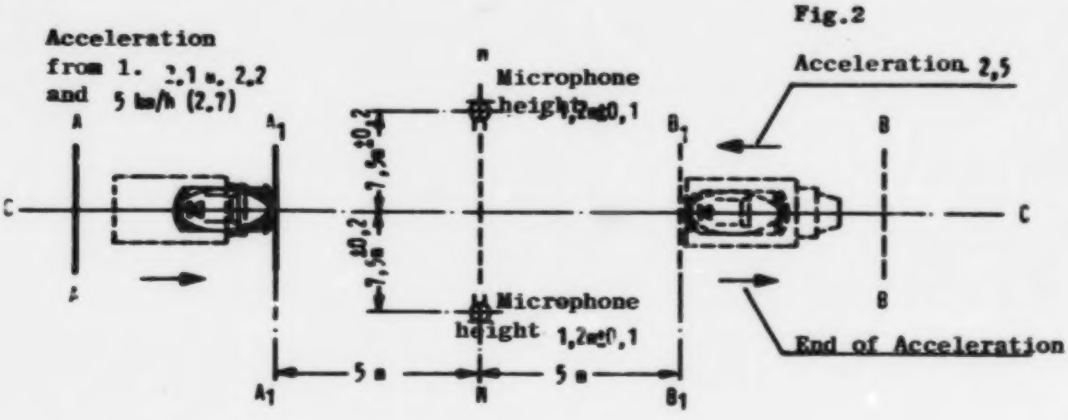
2.5 backing up

2.6 driving noise in 2. gear from 1/3 nN max

2.7 driving noise in 1. gear from 5 km/hr

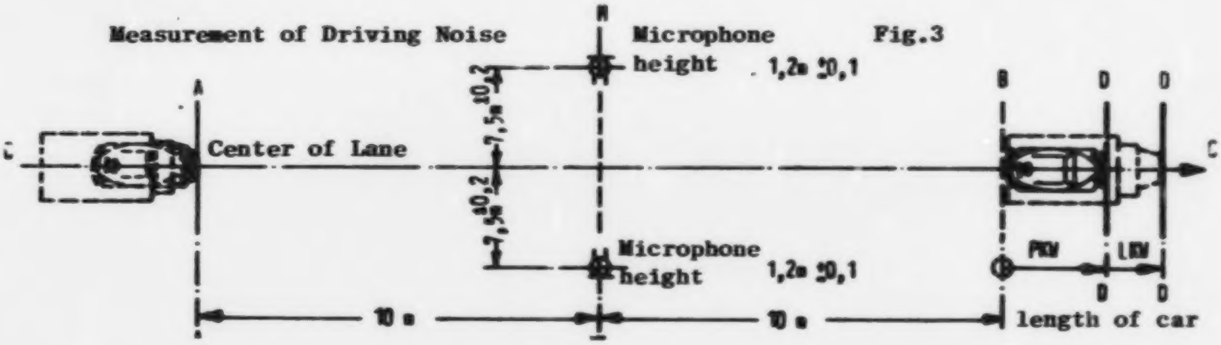
Measurement of Starting Noise and Noise Due to Acceleration in 1. Gear

Fig.2


Acceleration
from 1. 2,1 m, 2,2
and 5 km/h (2,7)
Acceleration 2,5
M
Microphone
height 1,2m±0,1
A
A1
B1
B
C
C
7,5m ±0,2
7,5m ±0,2
Microphone
height 1,2m±0,1
End of Acceleration
5 m
5 m
A1
M
B1

Measurement of Driving Noise

Fig.3


M
Microphone
height 1,2m ±0,1
A
B
D
D
C
Center of Lane
C
7,5m ±0,2
7,5m ±0,2
Microphone
height 1,2m ±0,1
PKW
LKW
D
D
10 m
10 m
length of car

3. Driving Noises at Various Constant Speeds on Horizontal Asphalt-Road (Choice of Gear see Testing Protocol) see Fig. 3

Driving Gear:

3.1 only for Cycles		2.(3.)	
3.2 30 km/hr	Passenger Cars see Testing Protocol	3.(4.)	Trucks as Passenger Cars, for 6-gear see Testing Protocol
3.3 50 km/hr		4.(5.)	
3.4 70 km/hr		4.(5.)	
3.5 100 km/hr			

4. Noise Levels at Various Speeds on Horizontal Asphalt-Road on Coasting (Rolling Noise) from Starting Speed See Fig. 3

4.1 only for cycles
4.2 30 km/hr
4.3 50 km/hr
4.4 70 km/hr
4.5 100 km/hr

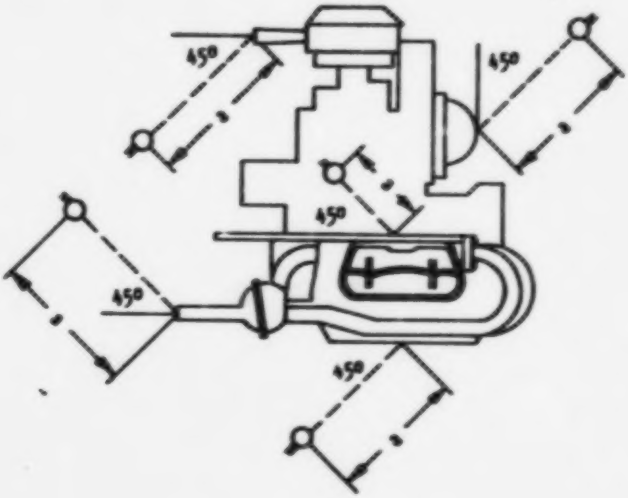
Short-Range Measurements of Alternate Acceleration

Test Distance: 2.5 / 5.5 / 11 cm

Valid Distance : see Testing Protocol

5.1 Intake opening
5.2 Exhaust muzzle
5.3 Cylinder Head (Various Positions)
5.4 Drive
5.5 Possibly Other Points (given individually)

Fig 4 Short-Range Meaurements. Distances: 2.5 cm
5.5 cm
11 cm

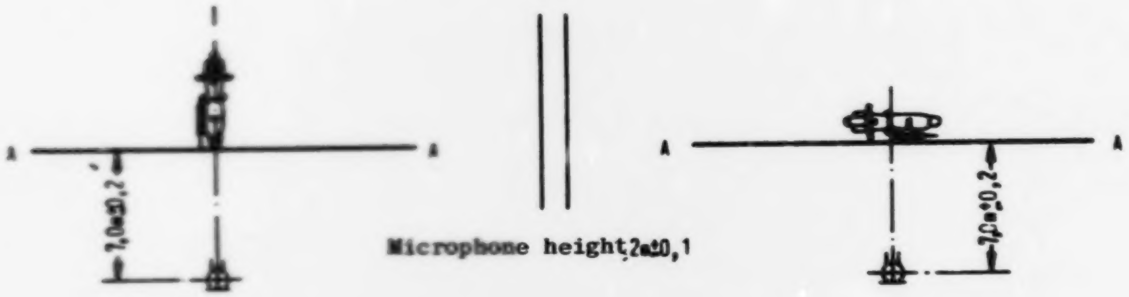


Extended Testing Program for Outer Noise within the Framework of the EG-Survey Cycles.

1. **Standing Noises**

Microphone arrangement 1:	Microphone arrangement 2:
7.0 m to the rear	7.0 m to the left
1.3 Start motor	1.31 start motor
1.4 Alternate Acceleration of the engine	1.41 alternate acceleration of the engine
1.5 as 1.4 but additional exhaust muffler (shunt battery)	1.51 as 1.41 but additional exhaust muffler (shunt battery)
1.6 idling of engine	1.61 idling the engine

Measuring the Standing Noises of Cycles Fig 1



2. **Driving Noises during Acceleration**
   - 2.1 Start of vehicle with normal acceleration
   - 2.2 Rapid start (limit of tire squealing)
   - 2.3 Full Power acceleration in 2. gear from 20 km/hr (15 km/hr for Mofas)
   - 2.4 Driving Noise according to StVZO
   - 2.6 Driving noise in 2. gear from 1/3 n Nmax
   - 2.7 Driving noise in 1. gear from 5 km/hr

Measurement of Starting Noise and Noise Due to Acceleration in 1. Gear

Fig.2

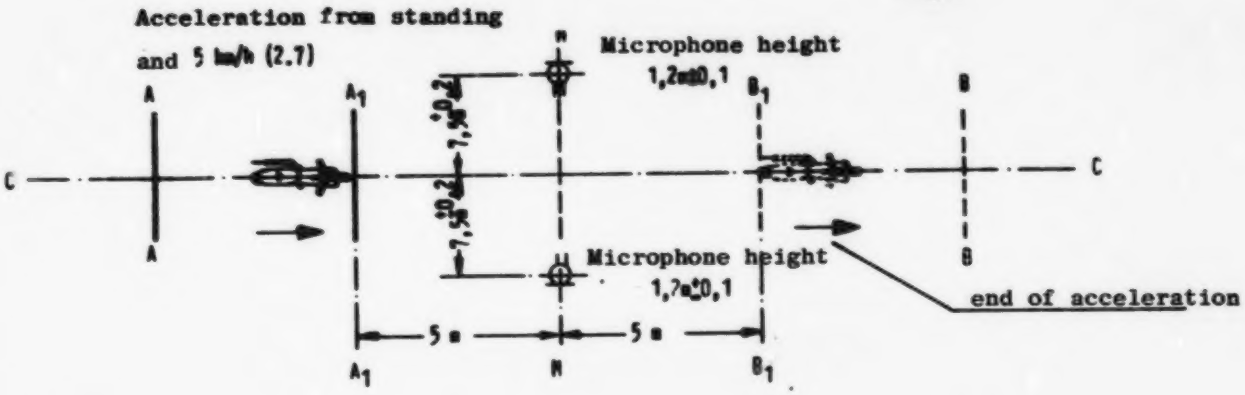
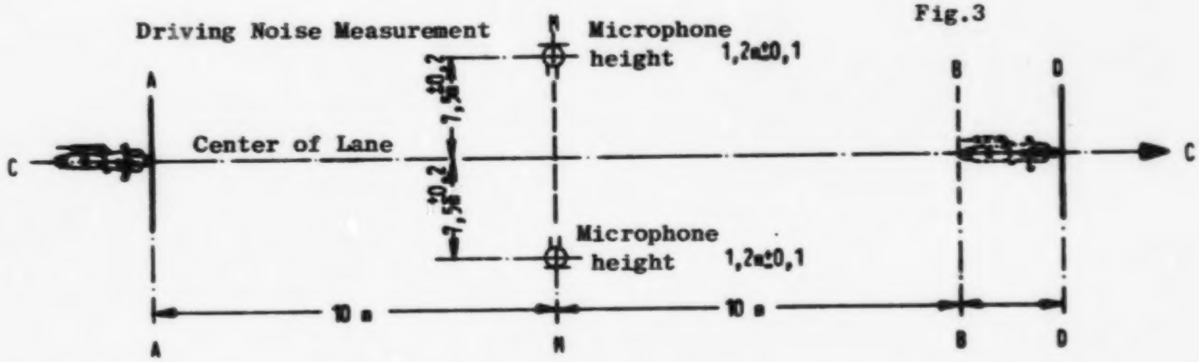

Acceleration from standing
and 5 km/h (2.7)
M
Microphone height
1,2m±0,1
A
A₁
B₁
B
C
C
7,5m±0,2
7,5m±0,2
A
Microphone height
1,2m±0,1
B
end of acceleration
5 m
5 m
A₁
M
B₁

Fig.3


Driving Noise Measurement
M
Microphone
height 1,2m±0,1
A
B
D
7,5m±0,2
Center of Lane
C
C
7,5m±0,2
Microphone
height 1,2m±0,1
10 m
10 m
A
M
B
D

3. **Driving Noises at Various Constant Speeds on Horizontal Asphalt-Road**

(Choice of Gear see Protocol)

3.1 20 km/hr Bicycle with Auxiliary Motor (Mofa) 20/25 km/hr
11 25 km/hr

3.2 30 km/hr Light Motorcycles up to 40 km/hr (Moped) 20/30/40 km/hr
21 40 km/hr

3.3 50 km/hr Light Motorcycles without Speed Limit 30/50/70 km/hr

3.4 70 km/hr

3.5 100 km/hr Motorcycles 30/50/70/100 km/hr

4. **Noise Levels at Various Speeds on Horizontal Asphalt-Roads on Coasting (Rolling Noise) from Starting Speed**

4.1 20 km/hr
11 25 km/hr Mofas 20 and 25 km/hr

4.2 30 km/hr
21 40 km/hr Mopeds 20/30/40 km/hr

4.3 50 km/hr

4.4 70 km/hr Light Motorcycles 30/50/70 km/hr

5. Short-Range Measurements at Alternate Acceleration

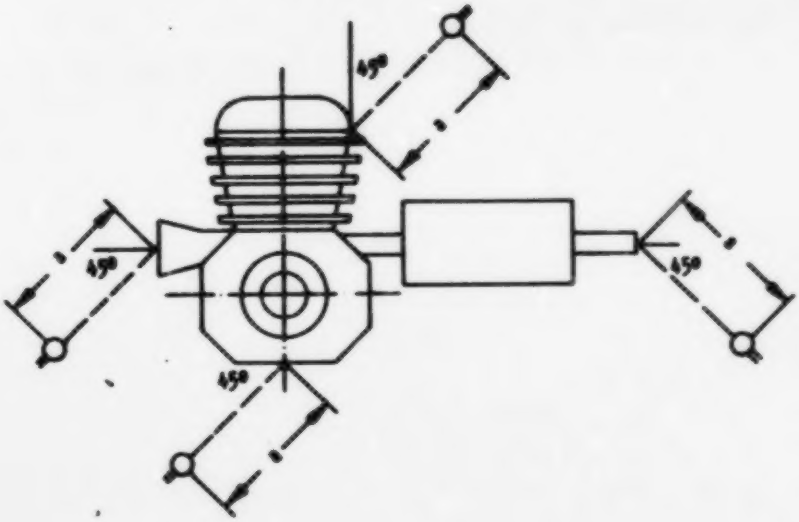
Testing Distance: 2.5 / 5.5 / 11 cm

Valid Distance: see Testing Protocol

5.1 Intake Opening
5.2 Exhaust Muzzle
5.3 Cylinder Head (Various Positions)
5.4 Drive
5.5 Possible Other Points

Fig. 4 Short-Range Measurement

Distances: 2.5 cm
5.5 cm
11 cm



Layout 3/1

Operating Conditions for Various Acceleration Processes: Passenger Cars

Vgl.Meßprogramm ①				2.41	2.411	2.412		2.4		2.61	2.611	2.612		2.6		2.71	2.711	2.712		--
			StVZO						1/3 n N max						1. Gang ⑫					
Schlüssel-Nr. Fahrzeuge ②	Motorart ③	Drehzahl bei N max ④	Gang ⑤	Anf.geschw. km/h ⑥	Motor U/min ⑦ Anfg. ⑧	Ende ⑨	⑩ % zu N max	Lautstärke dB(A) ⑪	Gang ⑤	Anf.geschw. km/h ⑥	Motor U/min ⑦ Anfg. ⑧	Ende ⑨	⑩ % zu N max	Lautstärke dB(A) ⑪	Gang ⑤	Anf.geschw. ⑥	Motor U/min ⑦ Anfg. ⑧	Ende ⑨	⑩ % zu N max	Lautstärke
[illegible]	Otto	4100	A	50	2000	2500	48/61	73,5	A	22	1360	2500	33/71	76,5	A	6	500	2600	[illegible]	[illegible]
[illegible]	"	4000	A	50	2100	2300	53/58	72,5	A	29	1330	2400	33/60	73	A	7	1000	2600	[illegible]	[illegible]
[illegible]	"	[illegible]	A	50	1850	2400	38/49	76	A	42	1630	[illegible]	33/41	[illegible]	A	8	1000	4900	[illegible]	[illegible]
[illegible]	"	4100	2	41	3075	3900	[illegible]	81	2	22	1360	2800	33/68	73,5	1	12	1000	4200	[illegible]	[illegible]
[illegible]	"	4000	2	48	3000	3600	75/90	79	2	29	1330	2600	33/65	73,5	1	9	1000	[illegible]	[illegible]	[illegible]
[illegible]	"	4900	2	50	3200	4000	65/81	80,5	2	28	1650	2800	33/57	76	1	10	1000	4000	[illegible]	[illegible]
[illegible]	"	5600	3	50	2100	2600	37/46	76,5	2	22	1900	3400	34/61	80,5	1	8	1200	5000	[illegible]	[illegible]
[illegible]	"	6400	3	50	2200	2600	34/40	76	2	20	2200	3400	34/52	79,5	1	8	1200	5000	[illegible]	[illegible]
[illegible]	"	4000	2	36	3000	4000	75/100	82,5	2	18	1330	3200	33/80	77	1	8	1000	[illegible]	[illegible]	[illegible]
[illegible]	"	4700	2	42	3600	4700	76/100	84	2	22	1570	3600	33/76	79,5	1	9	1300	5500	[illegible]	[illegible]
[illegible]	"	5500	2	50	4 00	5000	75/91	84,5	2	22	1830	3400	33/62	76	1	8	1000	4800	[illegible]	[illegible]
	"	5700	A 3	50	2300	3000	40/53	73,0	A 2	40	1900	2700	33/47	72,5	A	7	900	2500	[illegible]	[illegible]
	"	5000	A 3	50	2600	3200	52/64	71	A 2	30	1660	2500	33/56	71	A	7	700	3000	[illegible]	[illegible]
[illegible]	"	5300	A 3	50	1800	2600	34/49	68	A 2	42	1770	2600	33/49	70,5	A	7	800	2800	[illegible]	[illegible]
[illegible]	"	5200	A D	50	1750	2400	33/46	74	A D	32	1730	2600	33/50	72	A	6	1200	2150	[illegible]	[illegible]
[illegible]	"	5800	A 3.St.	50	2200	3000	38/52	74	2.St.	27	1930	3500	33/60	80,5	2.St.	6	1000	4400	[illegible]	[illegible]
[illegible]	[illegible]	5500	2	50	2500	3250	45/59	75	2	38	1830	3000	[illegible]	73,5	1	7	1500	[illegible]	24/46	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4000	56/70	79	[illegible]	[illegible]	1900	2700	33/47	76	1	7	[illegible]	[illegible]	[illegible]	[illegible]

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Layout 3/2

Operating Conditions for Various Acceleration Processes: Passenger Cars

Vgl.Meßprogramm 1				2.41	2.411	2.412		2.4		2.61	2.611	2.612		2.6		2.71	2.711	2.712		2.7
Schlüssel Nr.d. Fahrzeuge 2	3 Motor-art	Drehzahl bei N max 4	StVZO						1/3 a N max						1. Gang 12					
			5 Gang	6 Anf.geschw. km/h	7 Motor U/min 8 Anfg.	9 Ende	10 % zu N max	11 Lautstärke dB(A)	5 Gang	6 Anf.geschw. km/h	7 Motor U/min 8 Anfg.	9 Ende	10 % zu N max	11 Lautstärke dB(A)	5 Gang	6 Anf.geschw.	7 Motor U/min 8 Anfg.	9 Ende	10 % zu N max	11 Lautstärke
[illegible]	Otto	5000	2	50	3200	4000	64/80	79	2	23	1660	4000	33/80	73,5	1	5	800	4000	16/80	79
[illegible]	"	5300	2	50	2700	3700	51/69	77,5	2	30	1770	3200	33/60	74	1	5	900	4200	17/79	80
[illegible]	"	5200	2	50	3000	4200	58/81	78	2	28	1730	3000	33/57	71,5	1	6	1100	3600	21/69	[illegible]
[illegible]	"	5200	2	50	3700	4700	71/90	81,5	2	20	1730	2900	33/56	76,5	1	5	800	4300	16/82	79,
	"	5500	2	50	3800	4900	69/89	81	2	26	1825	3000	33/54	74	1	8	1300	4000	24/72	81
[illegible]	"	5800	2	50	3600	4600	62/79	82	2	25	1930	3500	33/60	79	1	7	1000	4000	17/69	79,
[illegible]	"	5800	2	50	3450	4500	59/77	81,5	2	35	1930	3600	33/62	77	1	5	800	5500	[illegible]	82,
[illegible]	Diesel	4200	2	42	3150	3700	75/88	79,0	2	24	1400	2700	33/64	73,5	1	5	800	3200	19/76	78
[illegible]	Otto	5000	2	48	3750	4300	75/86	81,5	2	31	1670	3200	33/64	75	2	6	950	4000	19/80	79
[illegible]	"	5400	2	50	4000	5000	74/92	76,5	2	24	1800	3400	33/63	69,5	1	7	1100	4600	20/89	74,
[illegible]	"	5400	2	50	4000	4600	74/85	80,5	2	23	1800	3100	33/57	74	1	7	1100	4300	20/80	80
129	"	5100	2	50	3400	4100	66/80	81	2	27	1700	2900	33/57	73,5	1	5	850	3100	17/61	76,
130	"	5500	2	50	3400	4300	62/78	78,5	2	25	1830	3300	33/60	76,5	1	8	1200	4200	22/76	77
[illegible]	"	5200	2	50	3300	4100	63/79	78,0	2	26	1730	3100	33/60	71,0	1	8	1100	4600	21/88	75
[illegible]	"	5600	2	50	3400	4300	61/77	81	2	30	1870	3250	33/58	77	1	7	950	4500	17/80	79,
[illegible]	"	5200	2	50	3900	4500	75/87	78	2	20	1750	3000	33/58	71	1	9	1200	4300	23/82	72,
[illegible]	"	5000	2	50	3300	3800	66/76	76,5	2	30	1670	2500	33/50	70,5	1	11	1300	3100	26/62	72,
[illegible]	"	5000	2	50	3350	3800	66/76	77	2	25	1670	2800	33/56	70,5	1	6	800	3300	16/62	75,

Layout 3/3

Operating Conditions for Various Acceleration Processes: Passenger Cars

Vgl.Meßprogramm 1				2.4	2.411	2.412		2.4		2.61	2.611	2.612		2.6		2.71	2.711	2.712		2.
Schl.Nr.d. Fahrzeuge 2	3 Motor-art	Drehzahl bei N max 4	StVZO						[illegible] N max						1. Gang 12					
			5 Gang	Anf.geschw. km/h 6	7 Motor U/min		10 % zu N max	Lautstärke dB(A) 11	5 Gang	Anf.geschw. km/h 6	7 Motor U/min		10 % zu N max	Lautstärke dB(A) 11	5 Gang	Anf.geschw. 6	7 Motor U/min		10 % zu N max	Lautstärke 11
					8 Anfg.	9 Ende					8 Anfg.	9 Ende					8 Anfg.	9 Ende		
	Otto	4800	2	48	3600	4200	7[illegible]/88	77,5	2	20	15[illegible]	3000	33/63	73	1	-	800	4200	17/88	75
[illegible]	"	5100	2	50	2900	3900	56/76	77,5	2	22	1700	2800	33/55	73,5	1	-	1300	4000	26/78	76
[illegible]	"	6400	2	50	4700	5400	74/84	82	2	22	2130	3400	33/53	75	1	-	1100	5500	17/86	77,
[illegible]	"	6000	2	50	4100	4900	68/82	78	2	22	2000	3200	33/53	73	1	-	1000	3900	17/65	73,
[illegible]	"	5400	2	50	3700	4500	68/83	81,5	2	28	1800	3500	33/65	75	1	-	1100	5200	22/96	61
[illegible]	"	5700	2	50	3600	4500	63/79	79,5	2	28	1900	3200	33/56	74	1	-	1000	5000	18/87	76,
[illegible]	"	6600	2	50	4500	5300	68/80	83	2	25	2100	3300	33/50	76,5	1	-	800	5600	12/54	80
[illegible]	"	4750	2	50	3400	4300	71/90	78,5	2	27	1575	2800	33/59	69,5	1	-	900	2800	19/59	74
[illegible]	"	5000	2	50	3100	3900	62/78	80	2	27	1670	3000	33/60	77,5	1	-	1100	4600	22/92	80
[illegible]	"	5500	2	50	2800	3400	51/62	80,5	2	27	1830	2900	33/53	75,5	1	-	1000	3800	18/69	79,
[illegible]	"	5500	2	50	3500	4300	64/78	82	2	25	1833	3000	33/55	77,5	1	-	800	4500	15/82	79,
[illegible]	"	5200	2	50	-	-		78	2	-	1740	2300		74	1	-	1000	2300	25/44	77
[illegible]	"	5750	2	50	3000	3800	52/66	77	2	22	1920	3000	33/52	71	1	-	800	4100	14/71	75,
[illegible]	"	5750	2	50	4200	5000	73/87	77	2	21	1913	3500	33/61	73	1	-	900	4300	16/75	74
[illegible]	"	5200	2	50	3300	4000	64/77	81	2	25	1725	3000	33/58	75,5	1	-	950	4300	18/83	77,5
[illegible]	"	5250	2	50	3950	4800	75/92	79	2	21	1750	3400	33/65	70	1	-	800	4500	15/86	74,5
[illegible]	"	5100	2	48	3825	4700	75/92	81	2	20	1700	3600	33/71	74	1	-	900	4500	18/88	78,5

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Operating Conditions for Various Acceleration Processes: Motorcycles

Vgl. Meßprogramm 1				2.41	2.411	2.412		2.4		2.61	2.611	2.612		2.6		2.71	2.711	2.712		2.7
			StVZO						1/3 n N max.						1. Gang/2					
					7 Motor U/min						7 Motor U/min						7 Motor U/min			
Schlüssel-Nr. 2 der Fahrzeuge	3 Motorart	4 Drehzahl bei N max	5 Gang	6 Anfangsgeschw. km/h	8 Anfang	9 Ende	10 % zu N max	11 Lautstärke dB(A)	5 Gang	6 Anfangsgeschw. km/h	8 Anfang	9 Ende	10 % zu N max	11 Lautstärke dB(A)	5 Gang	6 Anfangsgeschw. km/h	8 Anfang	9 Ende	10 % zu N max	11 Lautstärke dB(A)
700	Otto 2	7400	3	51	5400	6000	73 81	83,5	2	-	2450	5600	33 75	76,5	1	7	1200	7000	16 94	85,5
701	Otto 2	7400	3	50	5550	6100	75 82	81,5	2	17,5	2400	5400	32 73	73,0	1	5	1000	6500	14 88	80,5
702	Otto 4	6400	2	50	3500	4000	55 63	78,5	2	38	2130	3300	33 52	74,5	1	5	800	3400	14 53	74
703	Otto 4	6400	2	50	3300	4000	51 62	82,5	2	30	2130	3600	33 56	77,5	1	5	800	3500	14 55	81
704	Otto 4	6200	2	50	3200	4500	51 72	82	2	30	2070	4000	33 64	79	1	7	1000	3800	16 61	79
705	Otto 4	7400	2	50	3500	4800	47 65	84	2	35	2450	4200	33 57	82,5	1	7	1000	4000	14 54	83,5
706	Otto 4	8000	3	50	3000	4000	38 50	96,5	2	35	2700	5000	34 62	88	1	7	1000	5300	13 66	89
707	Otto 4	1000	3	50	6200	6500	62 65	81	2	25	3300	5500	33 55	78,5	1	12	1500	6000	15 60	82,5
08	Otto 2	8000	3	50	4200	4500	52 56	83	2	35	2600	4500	32 56	81,5	1	8	1000	4200	13 52	84

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Key to Layout 3 and Layout 4:

1. See Testing Program
2. Key numbers of vehicles
3. Type of motor
4. Revolutions at N max
5. Gear
6. Starting speed km/hr
7. Motor rpm
8. Beginning
9. End
10. Percent of N max
11. Sound intensity dB(A)
12. 1. Gear

Mathematical Formulae for the Determination of the Economics of Sound Proofing Measures for Various Types of Vehicles

1. Introduction

Different problems can justify the application of various formulae. For simple considerations the "unweighted expenditures in %" formula 1 or the "unweighted expenditures in DM/dB(A) level reduction" formula 2 may suffice.

But to permit the formulation of objective statements, equations are necessary that take into account the complex relationships between several acoustic phenomena and many effective quantities. Formulae 3 and 4 should therefore be preferred.

The calculation represents a suggestion trying to find objective norms. Since a relative valuation is concerned, the correlation to absolute values is of secondary importance.

2. Determination of the Formulae

Calculation of various economic indices (Expenditures) W_L in DM / dB(A) level reduction or %.

2.1 "Unevaluated expenditures in %" for an acoustic improvement.

Quantities to be calculated:

2.11 Expenditure A in DM for a given noise proofing technical measure.

2.12 The sales price Q of the vehicle or the product.

$$W_{L_1} = \frac{A \ . \ 100}{Q} \ \% \qquad \text{Formula 1}$$

Example:

1: A = 3,500.- DM
Q =70,000.- DM

$$W_{L_1} = \frac{3,500 \ . \ 100}{70,000} = 5\%$$

2.2 "Unevaluated Expenditure in DM / dB(A) level reduction"

Quantities to be calculated:

2.11 Expenditure A in DM

2.21 Total level reduction S_L in dB(A) for a given operating range.

$$W_{L_2} = \frac{A}{S_L} \quad \text{DM / dB(A) level reduction} \qquad \text{Formula 2}$$

Example:

$$2: \quad \begin{array}{ll} A & 1{,}500.\text{- DM} \\ S_L & \text{a dB(A)} \end{array} \qquad W_{L_2} = \frac{1{,}500}{4} = 375 \text{ DM / dB(A) level reduction}$$

2.3 "Weighted expenditure W_{L_3} in DM / dB(A) level reduction"

2.11 Expenditure A in DM

2.21 Total reduction in level S_L in dB(A) for a given operating range

2.31 Valuation factor for the operating range B

This factor weighs the degree of disturbance in the operating range in which the noise reduction is effective.

The factors are:		Factor
2.311	Rapid start and type inspection (StVZO)	4.0
2.312	Acceleration in 1. gear and partial acceleration in 2. gear from a speed of 20 km/hr	3.2
2.313	Normal start and partial acceleration from a speed of 1/3 nN max, 2. gear	2.7
2.314	Constant speed	2.0
2.315	Starting the motor	1.5
2.316	Idling	1.0

When a noise level reduction occurs in several ranges an average factor is to be used. Distribution indexes in urban traffic F_V (section 2.33) can be used here in percent or a simple averaging can be done.

For example for passenger cars:

A reduction of the noise level occurs:

	% Share	Factor B	(Product)
Idling	31	1.0	31.0
Start	7	2.7	18.9
+ partial acceleration from 20 km/hr	10	3.2	32.0
	48	6.9	71.9

Factor with partial distribution indices 71.9 : 48 = 1.5

Factor without partial distribution index 6.9 : 3 = 2.3

For a simple statement the arithmetic mean may suffice.

2.32 Valuation Factor for the Noise Level P (following table)

This quantity evaluates the measured noise intensity in dB(A) according to the noise level and takes into account the awareness exponent for the loudness (19).

Remark:

Different comparative measurements demonstrated the equivalence of the noise level so evaluated with the Sone-scale. For a simplification of the calculations the latter is therefore preferred.

2.33 Distribution factor F_V in city traffic from the EFZ (European driving cycle)

This quantity weighs the percentage-share of the various operating ranges and classes of vehicles in urban traffic.

Remark:

When a lowering of the noise level occurs only in one operating range only the corresponding value is to be considered, by simultaneous lowering in several operating ranges, the sum of the individual values:

the number of individual operating ranges.

Values for P:

Pegel dB(A)	P	Pegel dB(A)	P	Pegel dB(A)	P	Pegel dB(A)	P	Pegel dB(A)	P
50	2.00	60	4.00	70	8.00	80	16.0	90	32.0
51	2.14	61	4.29	71	8.57	81	17.1	91	34.3
52	2.30	62	4.59	72	9.19	82	18.4	92	36.8
53	2.46	63	4.92	73	9.85	83	19.7	93	39.4
54	2.64	64	5.28	74	10.60	84	21.1	94	42.2
55	2.83	65	5.66	75	11.30	85	22.6	95	45.3
56	3.03	66	6.06	76	12.10	86	24.3	96	48.5
57	3.25	67	6.50	77	13.00	87	26.0	97	52.0
58	3.48	68	6.96	78	13.90	88	27.9	98	55.7
59	3.73	69	7.46	79	14.90	89	29.9	99	59.7
60	4.00	70	8.00	80	16.00	90	32.0	100	64.0

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The following F_V values were determined:

Betriebsbereich	PKW	LKW ≤ 3,5 t	LKW > 3,5 t	Mofa	Moped	Klein-krafträder	Motor-räder
Leerlauf	31	31	31	31	31	31	31
Anfahren	7	17	11	12	12	10	8
Teilbeschleunigung 1/3 n Nmax 2. Gang	10	6	8	12	12	10	10
StVZO (Typprüfung)	6	6	6	8	8	5	0
Konstante Geschwindigkeit - Verzögerung ≈ 30 km/h	35	27	23	31	29	30	37
≈ 50 km/h	11	12	8	6	8*	14	14
Gesamt %	100	100	100	100	100	100	100

* = 40 - 45 km/h

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Remark:

Since the percent-share limits the duration of applicability, for purposes of calculations the value $\frac{100 - F_V}{10} = 0.1\ (100 - F_V)$ must be substituted.

$$W_{L_3} = \frac{A \cdot 0{,}1\ (100 - F_V)}{S_L \cdot B \cdot P} \quad \mathrm{DM/dB(A)} \qquad \text{Formula 3}$$

Remark:

The smaller the DM-values for W_{L_3} the better the economics. Expenditures rise exponentially when the required noise reduction measures approach the technically feasible limiting value.

The reduction of peak levels (high dB(A) values) and lowering of noise levels in ranges of a high disturbance index (B) improve the economics as does applicability in several operating ranges.

Example 3:

For a passenger car an improved exhaust muffler reduces the sound level in the operating modes "Partial accelerations from 1/3 nN max" and "Start" by 2 dB(A).

Expenditure: 50.- DM

Assumed level 78 dB(A) 1/3 nN max
" " 75 dB(A) start
S_L 4

Calculation:

W_{L_3} = [illegible]

[illegible]

This measure is very economical. Further examples in section 3.

2.4 "Weighted Expenditure W_{L_4} in % for a technical noise reduction"

Symbols as in formula 3

W_{L_4} = [illegible] Formula 4

Example 4 :

Basis: numbers as in example 3, Q = 6.000 DM

Calculation:

$W_{L_4} = \frac{50}{4} \cdot \frac{8,3}{6000} \cdot \frac{[illegible]}{2,7} \cdot \frac{100}{12,6}$ [illegible]

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The Calculation according to formula 2 (unweighted) would give:

$$W_{L_2} = \frac{50.100}{60} = 0.8\ \%$$

3. Numerical examples:

3.1 Truck above 3.5 t

Through Visco-ventilators and automatic transformer a noise reduction of 5 dB(A) is achieved during starts.

Expenditure A 3.600.- DM
Starting level 89 dB(A)

Calculation: (weighted cost)

$$W_{L_3} = \frac{3600}{5} \cdot \frac{0.1\,(100 - 11)}{2.7 \cdot 29.9} = \frac{30960}{403.6} \approx 76.95\ \text{DM / dB(A)}$$

This measure is still economical.

3.2 unweighted cost:

$$W_{L_2} = \frac{3.600.-}{5} = 720\ \text{DM / dB(A)}$$

Comparison between 3.1 and 3.2 clearly demonstrates that when the various factors are considered the weighted cost W_{L_3} has lower DM-values.

3.3 Expenditures in % (unweighted)

$$W_{L_1} = \frac{3600}{72000} \cdot 100 \qquad Q = 72000\ \text{DM}$$

$$W_{L_1} = \frac{360}{72} = 5\ \%$$

weighted expenditures in %

$$W_{L_1} = \frac{3600 \cdot 0.1\,(100 - 11) \cdot 100}{72000 \cdot 5 \cdot 2.7 \cdot 29.9}$$

$$W_{L_1} = \frac{36 \cdot 8.6}{7.2 \cdot 5 \cdot 2.7 \cdot 29.9} = \frac{309.60}{292.--}$$

$W_{L_1} \approx 1.06\ \%$ weighted cost

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3.5 Example: truck above 3.5 t

Total motor encasing with various supplemental devices

Overall cost A = 11,000.- DM

Noise reduction of 7 dB(A) during starts

starting noise level 87 dB(A)

Q = 70,000.- DM

$$W_{L_1} = \frac{11000 \cdot 100}{70000} = 13,7\ \%$$

3.6 $$W_{L_2} = \frac{11000}{7} = 1570,\text{-- DM / dB(A) noise reduction}$$

3.7 $$W_{L_3} = \frac{11000 \cdot 0,1\ (100 - 11)}{7 \cdot 2,7 - 26,0} = \frac{1100 \cdot 8,6}{7 \cdot 2,7 - 2,6}$$

$$= \frac{9160}{49,2} \approx 190\ \text{DM / dB(A) weighted}$$

The economics are to be checked carefully. Rather other measures should be evaluated that give more advantageous DM / dB(A) ratios.

3.8 $$W_{L_4} = \frac{11000 \cdot 0,1\ (100 - 11) \cdot 100}{7000 \cdot 7 \cdot 2,7 \cdot 26,0}$$

$$= \frac{1100 \cdot 8,6}{19 \cdot 2,7 \cdot 26,0} = \frac{9160}{[illegible]} = [illegible]$$

3.9 Trucks below 3.5 t

Noise reduction by means of encasing, Visco-ventilator, etc.

Reduction level StVZO-range 5 dB(A)

Starting level 83 dB(A)

Total cost 6,500.- DM

Price, Q 24,000.- DM

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$$W_{L_1} = \frac{6500 \quad 100}{24000} = 27 \%$$

According to Formula 1 this measure is not economically sound.

3.10 $W_{L_2} = \frac{6500}{5} = 1300 \text{ DM / dB(A)}$

3.11 $W_{L_3} = \frac{6500 \;.\; 0{,}1\,(100 - 6)}{5 \;.\; 4 \;.\; 19{,}7} = \frac{6500 \;.\; 9{,}4}{394}$

$= \frac{61200}{394} \approx 156{,}\text{-- DM / dB(A)}$ sound reduction.

First investigate other factors.